November 7, 2000

To: Interested Parties

TRANSMITTAL OF DRAFT AMENDMENTS TO LAHONTAN BASIN PLAN AND DRAFT ENVIRONMENTAL DOCUMENT, INDIAN CREEK RESERVOIR PHOSPHORUS TMDL AND HEAVENLY VALLEY CREEK SEDIMENT TMDL

The Lahontan Regional Board expects to consider adoption of two separate sets of amendments to the *Water Quality Control Plan for the Lahontan Basin* (Basin Plan), at its January 11-12, 2001 meeting in South Lake Tahoe to incorporate Total Maximum Daily Loads (TMDL) and implementation plans for Indian Creek Reservoir in Alpine County and for Heavenly Valley Creek in El Dorado County. The following documents are enclosed for your review:

- A Notice of Public Hearing/Notice of Filing
- The text of the proposed Indian Creek Reservoir amendments
- A draft environmental document for the Indian Creek Reservoir amendments
- The text of the proposed Heavenly Valley Creek amendments (including introductory language for a new Basin Plan section on TMDLs)
- A draft environmental document for the Heavenly Valley Creek amendments.

Detailed technical staff reports which explain the background for each set of amendments are also available on request.

The review period for the amendments and environmental document will extend from November 7 to December 22, 2000. Written comments should be submitted by the latter date, and directed to the attention of Judith Unsicker at the address above. To ensure proper routing of your comments, please mention the term "Basin Plan amendments" in the heading of your letter. If approved by the Regional Board, the amendments will not take effect until they receive further approvals by the State Water Resources Control Board, the California Office of Administrative Law, and the U.S. Environmental Protection Agency.

The existing (1995) Basin Plan and current and future draft amendments will be available on the Regional Board's webpage at the following address: <http://www.swrcb.ca.gov/rwqcb6/>. Questions about the amendments and environmental documents, or the plan amendment process, should be directed to Judith Unsicker at (530) 542-5462 or (email) unsij@rb6s.swrcb.ca.gov.

Sincerely,

Robert S. Dodds
Assistant Executive Officer

Enclosures

cc: (with enclosures) Regional Board Members
Greg Frantz, Division of Water Quality, SWRCB
Stefan Lorenzato, Division of Water Quality, SWRCB
Janet Whitlock, USEPA, c/o Division of Water Quality, SWRCB

JEU/shT:BPA2000jan01transmit.doc
["TMDLs- Indian Creek Reservoir" and "TMDLs- Heavenly Valley Creek" general files]

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

NOTICE OF PUBLIC HEARING
NOTICE OF FILING OF A DRAFT ENVIRONMENTAL DOCUMENT

In the Matter of Proposed Amendments
to the Water Quality Control Plan for the Lahontan Region

NOTICE IS HEREBY GIVEN that the California Regional Water Quality Control Board, Lahontan Region (RWQCB) will hold two public hearings to receive comments on two different sets of proposed amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan) and on draft "functional equivalent" environmental documents prepared pursuant to Section 21080.5 of the California Environmental Quality Act (CEQA). The proposed amendments would involve:

(1) Incorporation of a Total Maximum Daily Load (TMDL) for total phosphorus, and a TMDL implementation program, for Indian Creek Reservoir in Alpine County

(2) Incorporation of a Total Maximum Daily Load (TMDL) for sediment and a TMDL implementation program, for Heavenly Valley Creek in El Dorado County.

Draft environmental documents have been prepared for the proposed amendments, which conclude that that they will have no significant effects on the environment. The documents include analyses of socieoeconomic impacts and reasonable means of compliance with new pollution control requirements. Consultation with El Dorado County and Alpine County staff indicates that there are no sites within either watershed on the list of hazardous waste sites maintained under Government Code Section 65962.5. The technical justification for the proposed amendments is provided in separate staff reports, which are available on request.

The public hearings will be held as follows:

DATE: Thursday and Friday, January 11-12, 2001

TIME: During the RWQCB's regular meeting, which begins at 7:30 p.m. Wednesday

PLACE: City Council Chambers
1900 Lake Tahoe Boulevard
South Lake Tahoe, CA

At the conclusion of each public hearing, the RWQCB will consider certification of the environmental document and approval of the proposed amendments.

The public review period for the proposed amendments and CEQA documents will extend from November 7 to December 22, 2000. Written comments or questions on the amendments and environmental documents should be directed to the attention of Judith Unsicker at the address below. Her telephone number is (530) 542-5462. Please include the term "Basin Plan Amendments" in the heading of your comments to ensure proper routing.

The draft amendments and environmental documents will be available on the Regional Board's Internet webpage at <http://www.swrcb.ca.gov/rwqcb6>. Copies of these documents may be obtained by calling (530) 542-5400. Copies of the Basin Plan, the proposed amendments, the environmental documents, and related materials may be examined and photocopied on weekdays between 8:30 a.m. and 4:30 p.m. at the RWQCB's office, 2051 Lake Tahoe Boulevard, South Lake Tahoe, CA 96150.

__________________________________ Date: ________________

Robert S. Dodds
Assistant Executive Officer

Draft

Amendments to the *Water Quality Control Plan for the Lahontan Region*
Concerning

Total Maximum Daily Load and Implementation Plan for Indian Creek Reservoir, Alpine County California

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Blvd
South Lake Tahoe CA 96150

November 2000

Contact Person:

Judith Unsicker
Environmental Specialist IV (Specialist)
Telephone: (530) 542-5462
Fax: (530) 542-5470
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The following language is proposed to be inserted into Chapter 4, Section 4.13 of the Basin Plan. If the amendments are approved, corresponding changes will be made to the "Record of Amendments" page, the Table of Contents, the List of Tables, page numbers, and page headers in the plan. Due to the Basin Plan's two-column page layout, the location of tables in relation to text may change during final formatting of the amendments.

"Indian Creek Reservoir, Alpine County

Problem Statement. Indian Creek Reservoir was constructed in 1969-70 on an ephemeral tributary of Indian Creek, a tributary of the East Fork Carson River. The reservoir was designed to store tertiary wastewater effluent exported from the Lake Tahoe watershed for later use in pasture irrigation, and to support a trout fishery. The U.S. Bureau of Land Management operates a campground and day use facilities near the reservoir. The reservoir became eutrophic during the 1970s, and was placed on the Section 303(d) list for eutrophication in the 1980s. The South Tahoe Public Utility District (STPUD) discontinued wastewater disposal to Indian Creek Reservoir in 1989, and acquired water rights to maintain a minimum reservoir level to support recreational uses. Monitoring showed decreases in the concentrations of most wastewater-related constituents after wastewater disposal ceased. Concentrations of total phosphorus decreased but remained at levels which the scientific literature indicates will maintain eutrophic conditions, apparently due to internal loading from the sediment. The reservoir continued to show symptoms of eutrophication including blooms of blue-green algae, low transparency, and depletion of dissolved oxygen in the hypolimnion. Total phosphorus was selected as the focus of the TMDL for the reservoir, since reduction of phosphorus loading was considered the most crucial factor in controlling eutrophication. The technical background for the TMDL and implementation plan is summarized in a staff report (California Regional Water Quality Control Board, Lahontan Region, 2000) which is available on request.

Numeric Targets and Indicators. The primary numeric target for the Indian Creek Reservoir is an annual mean concentration in the water column of 0.02 mg/L total phosphorus. This target is lower than the water quality objective (0.04 mg/L, mean of monthly means), which was based on the water quality achievable when the reservoir was receiving tertiary wastewater effluent, and represents the threshold between mesotrophic and eutrophic conditions. Mesotrophic conditions should adequately protect aquatic life and recreational uses of the reservoir. Based on the literature review and modeling of tributary water quality, the target can feasibly be attained if phosphorus in the sediment is removed or inactivated. Other numeric targets and indicators will be used to evaluate progress toward abatement of eutrophic conditions. Targets and indicators for the TMDL summarized in Table 4.13-ICR-1.

Table 4.13-ICR-1. Numeric Targets and Indicators for Indian Creek Reservoir TMDL

Indicator	Target Value	Reference
Indian Creek Reservoir*		
Total P concentration	No greater than 0.02 mg/L, annual mean	USEPA, 1988, 1999.
Dissolved Oxygen	Shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L at any time, whichever is more restrictive.	(Water quality objective for surface waters of Indian Creek watershed)
Secchi depth	Summer mean no less than 2 meters	USEPA, 1988. 1999
Chlorophyll a	Summer mean no greater than 10 ug/L	USEPA, 1988,1999
Carlson Trophic Status Index	Composite index no greater than 45 units	USEPA 1988, 1999
Tributary Inflow Ditch**		
Total P Concentration	No greater than 0.0225 mg/L, ten year rolling average	Concentration which corresponds to load allocation.

* These indicators will be measured for at least one depth profile sampling station.
**This indicator will be measured at the established monitoring station closest to the reservoir.

Source Analysis. Indian Creek Reservoir has no natural tributary streams. Phosphorus enters the reservoir in water diverted from the West Fork Carson River and Indian Creek, in precipitation and direct surface runoff, and by internal loading from the sediment. Internal loading is the most important source of phosphorus. The estimated "existing" loads are based on modeling of tributary inputs using water quality and flow data for 1999, literature sources to estimate precipitation and runoff inputs, and internal phosphorus loading rates. Numbers are rounded to the nearest pound. The “tributary inflow” source represents combined diversions from West Fork Carson River and Indian Creek. All sources are considered to be nonpoint. Estimated loads from all sources are summarized in Table 4.13-ICR-2.

Loading Capacity. Assuming complete mixing and a reservoir volume of 1515 acre feet (at the minimum staff gage level maintained under an agreement between STPUD and Alpine County), the maximum amount of phosphorus which can be present in the water column if a concentration of 0.02 mg/L total phosphorus is to be maintained is 82 lb/yr.

Table 4.13-ICR-2 Estimated Existing Phosphorus Loads to Indian Creek Reservoir from External and Internal Sources (rounded to the nearest pound)

Source	Load (pounds per year) and % of total
EXTERNAL SOURCES	
Precipitation	3
Direct surface runoff	68
Tributary inflow	43
Minor sources*	0
A. Total External Load	114 [24%]
INTERNAL SOURCES	
Total anoxic load (by literature formula for 120 day stratification period)	204
Total oxic load (by subtraction)	150
B. Total Internal Load (lb/yr)	354 [76%]
C. Loss in Reservoir outflow (lb/yr)	137
TOTAL LOAD (A + B)	468
NET WATER COLUMN LOAD (A + B - C)	331

*Loading and losses from the minor sources and sinks discussed in the staff report are considered *de minimis.*

Table 4.13-ICR-3. Load Allocations for Indian Creek Reservoir

Source	Load Allocation (lb/ yr)
EXTERNAL	
Precipitation	3
Direct Surface Runoff*	17
Tributary Inflow*	32
Total external allocation	*52*
INTERNAL	
Total internal allocation	46
OUTFLOW	18
Total Load Allocation	98
Net Load Allocation*	80

* Allocations for these parameters are interpreted as 10 year rolling averages to account for seasonal and annual variability.

** This allocation is to the water column, with the assumption that an additional 18 lb/yr of internally derived phosphorus will leave the reservoir in the outflow.

Load Allocations. There are no point sources of phosphorus loading to Indian Creek Reservoir, and the wasteload allocation is thus zero. Load allocations for external and internal nonpoint sources of phosphorus are summarized in Table 4.13-ICR-3. The load allocations for external sources assume no reduction in phosphorus loading from precipitation, a 75% reduction in loading from surface runoff and tributary inflow, and an 87 % reduction in internal loading.

Loading capacity linkage analysis. The loading capacity and the associated numeric target for phosphorus are based on a strong quantitative framework, developed through a large set of empirical scientific data, that allows for the prediction of algal biomass and other associated water quality parameters from nutrient loading and water column nutrient concentrations (USEPA, 1999). The proposed phosphorus concentration target corresponds to a literature threshold between mesotrophic and eutrophic conditions. The literature review summarized in the staff report indicates that the proposed numeric target and the associated loading capacity, if attained, will be adequate to protect designated aquatic life and recreational uses of Indian Creek Reservoir, the beneficial uses most likely to be impaired by eutrophication, and to ensure compliance with applicable narrative water quality objectives.

Margin of safety. The Indian Creek Reservoir TMDL provides an implicit margin of safety by:

1. Interpreting compliance with standards (including beneficial use support and progress from eutrophic to mesotrophic conditions) through multiple targets and indicators.

2. Incorporating conservative assumptions in the source analysis and development of load allocations. Assumptions which provide a margin of safety include:

- Development of the TMDL for total phosphorus rather than for orthophosphate or "soluble reactive phosphorus", which are the forms of phosphorus most readily available to plants. The analysis assumes that all P in the system, including sediment P, will eventually be recycled and made biologically available.

- The "worst case" assumption that all phosphorus released from the sediment during summer stratification is made available for algal growth in the hypolimnion during the summer.

Seasonal and interannual factors and critical conditions. The TMDL for Indian Creek Reservoir accounts for seasonal and annual variations in external and internal phosphorus loading, and associated impacts on beneficial uses in several ways:

- The load allocations for surface runoff and tributary inflow are set as a 10 year rolling averages to account for seasonal and annual variations in runoff, tributary flows, and phosphorus concentration.

- The most critical conditions for attainment of aquatic life and recreational uses in Indian Creek Reservoir occur during summer stratification, when the greatest release of phosphorus from the sediment occurs and warm temperatures promote depletion of oxygen in the hypolimnion. Attainment of the loading capacity will require removal or inactivation of phosphorus in the sediment of Indian Creek Reservoir. The shallow dimensions of the reservoir will continue to cause stratification, but reduced phosphorus loading will reduce the risk of oxygen depletion.

Implementation Plan. Implementation of the TMDL is the responsibility of the STPUD (for control of internal phosphorus loading) and of the U.S. Bureau of Land Management, Alpine County, STPUD, and other land owners and land managers in the watershed (for control of external sources). The implementation program does not specify the means of compliance with the TMDL, but rather establishes a process for identification and implementation of controls for external and internal sources of phosphorus loading to Indian Creek Reservoir. (The Regional Board is prohibited by Section 13360 of the California Water Code from specifying the manner of compliance with its orders.)

Implementation will be done in coordination with the Regional Board's ongoing watershed management planning and nonpoint source control efforts. The Regional Board intends to implement the TMDL through the "three-tiered" approach outlined in the statewide *Plan for California's Nonpoint Source Pollution Control Program.*

The implementation process will include the following:

1. For control of all sources:

Within 3-4 months after final approval of the TMDL, Regional Board staff will convene a stakeholder group for ongoing discussion of and communication about TMDL issues, including but not limited to STPUD, USBLM, and Alpine County staff and other public and private landowners in the watershed which contributes external phosphorus loading to Indian Creek Reservoir. Participation should also be invited from staff of the U.S. Natural Resource Conservation Service, the Alpine Resource Conservation District, and downstream stakeholders in California and Nevada, including the Nevada Division of Environmental Protection, the Upper Carson River Coordinated Resource Management Plan group and the Carson Water Subconservancy.

2. For control of external loading:

- By 1 year after TMDL approval Regional Board staff and stakeholders will identify specific sites needing BMPs for phosphorus control within the watershed that contributes direct surface runoff to Indian Creek Reservoir.

- By 1 year after TMDL approval , Regional Board staff and stakeholders will identify specific sites needing BMPs for phosphorus control on public and private lands within the watershed tributary to the irrigation ditch which provides inflow to Indian Creek Reservoir from Indian Creek and the West Fork Carson River.

- By 2-3 years after TMDL approval, depending on progress toward "self determined" implementation of BMPs ("Tier 1" implementation under the statewide nonpoint source control plan), Regional Board staff will request reports of waste discharge to document the BMPs proposed for implementation. Staff will consider the need for conditional waivers ("Tier 2") or waste discharge requirements ("Tier 3") to ensure implementation of BMPs.

- Within 3-4 years after TMDL approval, BMPs will be implemented for source areas contributing to external loading of phosphorus to Indian Creek Reservoir. The statewide nonpoint source control plan (California State Water Resources Control Board, 2000) requires implementation of management measures for *agricultural* nonpoint sources by 2003, and management measures for all nonpoint sources by 2013.

3. For control of internal loading:

- Immediately after TMDL approval, Regional Board staff will use Porter Cologne Act Section 13267 authority to request a report from the STPUD on the method(s) it intends to use to reduce internal loading of phosphorus to Indian Creek Reservoir from the sediment.

- By 15 months after TMDL approval, STPUD will investigate the feasibility of controls for internal phosphorus loading to Indian Creek Reservoir and submit a plan for approval by the Regional Board. Depending upon the nature of the proposed action, the Regional Board may provide direction to staff for implementation, issue waste discharge requirements and/or a formal monitoring program for activities to control internal phosphorus loading, or take other appropriate action.

- By 4-5 years after TMDL approval STPUD will fully implement controls for internal phosphorus control.

Attainment of the TMDL targets and the narrative water quality objectives related to protection of beneficial uses are projected to occur by 2024.

Potential implementation measures include Best Management Practices (BMPs) to control external sources of phosphorus loading, and in-lake measures to remove phosphorus-rich sediment or inactivate the internal phosphorus release process. Agricultural BMPs potentially relevant to control of external phosphorus loading to Indian Creek Reservoir include: Range and pasture management, proper livestock to land ratios, irrigation management, livestock waste management; fences (livestock exclusion); retention/detention ponds, constructed wetlands, streambank stabilization, sediment ponds; and riparian buffers (USEPA, 1999). Additional potentially relevant nonpoint source management measures include: education outreach, runoff control for existing development, road, highway and bridge runoff systems, marina and recreational boating management measures (including shoreline stabilization), instream habitat restoration, and vegetated treatment systems.

Further study will be necessary to identify the best and most cost effective in-lake phosphorus control method(s) for Indian Creek Reservoir, but based on the literature review summarized in the staff report, both phosphorus inactivation (by one of several chemical methods) and phosphorus removal (by dredging or bulldozing) appear to have the potential for rapid attainment of the numeric target. Other potential control methods include hypolimnetic withdrawal, hypolimnetic oxygenation, biomanipulation, and treatment systems involving harvest of periphyton to remove nutrients.

The BMPs and lake restoration measures summarized the staff report are technically feasible and have been shown to be effective in reducing phosphorus loading and/or abating eutrophic conditions. The Regional Board recommends that, in addition to the selected in-lake treatment measure(s), STPUD should use the full amount of its existing water rights, under the constraints imposed by the Alpine Decree, in a manner which will maximize fresh water inflow into Indian Creek Reservoir.

Monitoring. The proposed TMDL monitoring plan involves continuation of current monitoring by the STPUD of Indian Creek Reservoir and its tributary inflow. (Not all of the parameters sampled are necessary for determining compliance with TMDL load allocations.) Regional Board staff recognize that sampling parameters, stations and frequencies may need to be changed over time as a result of an adaptive management approach to implementation. Consequently, the Basin Plan does <u>not</u> specify sampling parameters, locations and frequencies. The Regional Board's Executive Officer may adopt a formal monitoring program for Indian Creek Reservoir and its tributary inflow pursuant to the California Water Code, and changes in this program may be made over time without the necessity for further Basin Plan amendments.

The TMDL monitoring program is expected to involve:

- monitoring of tributary inflow and water quality (including P concentration);
- monitoring of Indian Creek Reservoir including gage height, water quality, and algal cell/colony counts,
- monthly depth profile measurements in Indian Creek Reservoir including dissolved oxygen and temperature
- monthly measurements of total phosphorus concentrations at several depths including the hypolimnion
- monthly measurement of chlorophyll a at the near-surface depth
- monthly measurements of Secchi depth in Indian Creek Reservoir during the stratification period

- periodic inspections of BMPs, once they have been installed.

The phosphorus concentration and inflow amounts of precipitation and surface runoff to the reservoir will not be measured directly; the success of BMPs to reduce phosphorus runoff to Indian Creek Reservoir will be assessed through measurements of reservoir quality**.**

Schedule for review and revision of the TMDL. Regional Board staff will continue to review monitoring reports on an ongoing basis, and will discuss them with STPUD and other stakeholders periodically. Comprehensive reviews of monitoring data and progress toward implementation and attainment of targets will be conducted at five year intervals. Because some of the targets and load allocations are expressed as ten year rolling averages to account for seasonal and annual variability, the first decision point on the need for revision of the TMDL will not occur until after the comprehensive review held in the tenth year.

References:

The following references will be added to the Basin Plan's bibliography. Citation in the amendment language above is not meant to imply incorporation by reference.

California Regional Water Quality Control Board, Lahontan Region, 2000. *Technical Staff Report: Total Maximum Daily Load and Implementation Plan, Indian Creek Reservoir, Alpine County, California*.

California State Water Resources Control Board, 2000. *Plan for California's Nonpoint Source Pollution Control Program*.

U.S. Environmental Protection Agency, 1988. The Lake and Reservoir Restoration Guidance Manual, First Edition. EPA 440/5-88-002 February 1988

U.S. Environmental Protection Agency, 1999. *Protocol for Developing Nutrient TMDLs, First Edition.* EPA 841-B-99-007, November 1999.

DRAFT

ENVIRONMENTAL DOCUMENT FOR

TOTAL MAXIMUM DAILY LOAD AND IMPLEMENTATION PLAN FOR INDIAN CREEK RESERVOIR, ALPINE COUNTY, CALIFORNIA

STATE CLEARINGHOUSE NUMBER 98092052

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe, California 96150
(530) 542-5400

November 2000

Contact Person:

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SUMMARY

The proposed action is adoption of amendments to the Lahontan Basin Plan to incorporate a Total Maximum Daily Load (TMDL) and TMDL implementation plan to control phosphorus loading to Indian Creek Reservoir in the Carson River watershed, Alpine County, California. Due to eutrophication related to nutrients from wastewater, Indian Creek Reservoir was placed on the Clean Water Section 303(d) list of impaired water bodies requiring TMDLs during the 1980s. The TMDL would require a 75 reduction in external loading and an 87 percent reduction in internal loading of phosphorus to the reservoir. The implementation plan would establish a process and schedule for selection and implementation of Best Management Practices to control external sources, and in-lake restoration methods to remove phosphorus-laden sediment or reduce phosphorus release from the sediment, in order to control internal loading. Potential control measures, and their socioeconomic implications, are discussed. This environmental document concludes that the proposed action will not have any significant direct adverse environmental impacts (defined as physical changes in the environment) but that indirect impacts could occur from implementation projects. Because specific implementation measures have not yet been selected, the environmental impacts of those projects must be analyzed and mitigated in future project-specific environmental documents. This environmental document discusses indirect impacts and potential mitigation measures in a general manner, and identifies alternatives to the proposed Basin Plan amendments. Controversial issues associated with the proposed action include the need for the TMDL, the feasibility of attaining the phosphorus target and load allocations, and the socioeconomic impacts of implementation. Total estimated implementation costs range from $0.7 to 1.5 million.

BACKGROUND

The California Regional Water Quality Control Board, Lahontan Region (Regional Board) is the State agency responsible for setting and enforcing water quality standards, under the federal Clean Water Act and the California Water Code, for about 20 percent of California east of the Sierra Nevada crest and in the northern Mojave Desert. Water quality standards and control measures are set forth in the *Water Quality Control Plan for the Lahontan Region* (Basin Plan). The Basin Plan was last revised in 1995.

Indian Creek Reservoir (ICR) in eastern Alpine County (Figures 1 and 2) was constructed to store tertiary-treated wastewater exported from the Lake Tahoe Basin by the South Tahoe Public Utility District (STPUD). The wastewater was later used for pasture irrigation on private lands in the Carson River watershed. The reservoir was also designed to serve as a recreational trout fishery, but became eutrophic due to high nutrient loads. Because of this eutrophication, ICR was placed on the list of impaired water bodies required under Section 303(d) of the federal Clean Water Act. Although disposal of wastewater to the reservoir ceased in 1989, and STPUD purchased water rights to maintain reservoir levels, it is still eutrophic. The Clean Water Act requires preparation of “Total Maximum Daily Loads” (TMDLs) for listed water bodies. TMDLs are strategies to reduce pollutant loads from point and nonpoint sources in order to ensure attainment of water quality standards. Phosphorus has been chosen as the nutrient for which loads must be reduced in order to reduce eutrophication and to protect and enhance recreational and aquatic life uses of ICR.

The Lahontan Regional Board's planning process has been certified by the California Secretary for Resources under Section 21080.5 of the California Environmental Quality Act (CEQA) as "functionally equivalent" to the preparation of an Environmental Impact Report (EIR). This certification allows the Regional Board to prepare a relatively short "functional equivalent" document rather than a lengthy EIR for proposed Basin Plan amendments. The environmental document must still contain all the elements of an EIR, and must be circulated for an equivalent public review period.

The Regional Board two "Notices of Preparation" pursuant to CEQA for this project, the first in September 1998, and the second in May 2000. The second notice was necessary due to revisions in the project description. This environmental document addresses environmental impacts, socioeconomic impacts, agricultural water quality control measures, and "reasonable means of compliance" with new pollution control requirements as required by CEQA and the California Water Code. A separate technical staff report, which is available on request, discusses the background for each element of the TMDL, and the implementation program.

PROJECT DESCRIPTION

The Regional Board proposes to adopt amendments to the Lahontan Basin Plan to incorporate a TMDL and TMDL implementation plan to reduce loads of total phosphorus to ICR. The numeric target for the TMDL will be set at 0.02 mg/L total phosphorus, which the scientific literature indicates will maintain mesotrophic rather than eutrophic conditions. The current water quality objective for total phosphorus (0.04 mg/L), was set in 1975 based on conditions which could be achieved when the reservoir was receiving tertiary wastewater effluent. The average total phosphorus concentration in the reservoir in 1999 was 0.08 mg/L. A literature search indicates that a total phosphorus concentration at the level of the objective would maintain eutrophic conditions even if it were attained. Based on the literature, attainment of the new target should , over the long term, result in mesotrophic conditions in the reservoir and reduced risks of blue green algae blooms, reduced water clarity, low dissolved oxygen levels, fish kills, and other symptoms of eutrophication. The existing water quality objective is not proposed for revision at this time.

The TMDL includes other indicators and targets in addition to the phosphorus concentration target above. These indicators are dissolved oxygen, chlorophyll a, Secchi depth transparency, and the Carlson Trophic State index. The index allows evaluation of phosphorus concentration, Secchi depth, and chlorophyll a to each other and to measurements taken in other lakes.

Indian Creek Reservoir received a large historic load of phosphorus from wastewater. Much of this phosphorus is believed to be stored in the reservoir sediment and to be potentially available for recycling in to the water column, where it can fuel the growth of algae and larger aquatic plants (“macrophytes”). The reservoir also receives some phosphorus from external sources, including tributary inflow diverted from Indian Creek and the West Fork Carson River, direct runoff from its watershed, and precipitation. The amendments include estimates of existing phosphorus loads from and “load allocations” to, both external and internal nonpoint sources. (There are no current point sources of phosphorus loading to ICR, so the TMDL "wasteload allocation" is zero.) The load allocations estimate the amount of phosphorus loading which must be reduced from each source in order to attain the numeric phosphorus concentration target which corresponds to the loading capacity or "Total Maximum Daily Load". A 75 percent reduction in external loading and an 87 percent reduction in internal loading (calculated from 1999 conditions) is required. The implementation plan establishes a process for the selection and implementation of Best Management Practices (BMPs) to reduce external phosphorus loading from the watershed, and in-lake measures to treat or remove reservoir sediment to reduce internal phosphorus loading. (Reduction of internal loading is essential for timely attainment of the target and protection of aquatic life and recreational uses of the reservoir. Currently available water supplies for dilution and flushing are <u>not</u> adequate, by themselves, to ensure attainment)

Responsibility for implementation will be allocated to the STPUD and to landowners in the watershed, including the U.S. Bureau of Land Management and other public and private parties. Specific implementation measures have not yet been determined. The TMDL implementation plan relies on the "three-tiered" approach of the California State Water Resources Control Board's (2000) statewide *Plan for California's Nonpoint Source Pollution Control Program* (Nonpoint Source Plan). The three-tiered approach begins with "self-determined implementation of management practices" and proceeds through "regulatory based encouragement of management practices" and "effluent limitations and enforcement actions". The Nonpoint Source Plan stresses that "self-determined" implementation is <u>not</u> "voluntary" implementation . All landowners in California are expected to implement measures to control nonpoint source pollution within the schedules set forth in the plan. These schedules, which are referenced in the TMDL implementation program for ICR, call for implementation of management measures for agricultural nonpoint sources by 2003, and for implementation of all management measures by 2013.

Additional information on potential implementation measures is presented in the discussion of environmental and socioeconomic impacts, below. The TMDL implementation program includes monitoring to evaluate the success of the implementation measures and progress toward attainment of the numeric target. It also includes provisions for periodic review of the TMDL, and for revisions if necessary in the future.

APPROVALS REQUIRED

After their adoption by the Lahontan Regional Board, the Basin Plan amendments must be approved by the California State Water Resources Control Board, the California Office of Administrative Law, and the U.S. Environmental Protection Agency (USEPA) before taking effect. Legislation adopted in 1997 requires the California Environmental Protection Agency, and its member agencies including the State and Regional Water Boards, before taking final action on new regulations, to submit information on the scientific basis for those regulations for external scientific peer review. An earlier version of the proposed amendments was peer reviewed in 1999, and the current project reflects changes suggested by the reviewer. Specific responses to peer reviewer comments will be included in the administrative record of the amendments.

Adoption of the Basin Plan amendments will not in itself have physical effects on the environment. However, the TMDL implementation program will lead to other specific projects which could physically change the environment. These projects may require their own environmental documents under CEQA or the National Environmental Policy Act (NEPA). Potential lead agencies for future CEQA or NEPA documents include STPUD, Alpine County, the Alpine Resource Conservation District, the U.S. Natural Resource Conservation Service, the U.S. Bureau of Land Management, and the U.S. Forest Service, Humboldt-Toiyabe National Forest. The Regional Board’s environmental document is not expected to be used in permitting by any “lead agencies” or "responsible agencies" under CEQA for either the amendments or future implementation projects.

ENVIRONMENTAL AND SOCIOECONOMIC SETTING

Indian Creek Reservoir was constructed on a small ephemeral tributary of Indian Creek. Indian Creek itself joins the East Fork Carson River in Nevada. It has undergone considerable hydrologic modification related to agricultural diversions and to construction of the separate Harvey Place Reservoir, which is now used to store wastewater from STPUD for irrigation. Indian Creek Reservoir has no natural tributary streams, and most of its current water inflow comes from diversions from Indian Creek and the West Fork Carson River. Due to the constraints of available water rights, the inflow water is used to maintain the level of the reservoir, and rarely provides for any flushing. Inflow water travels several miles through unlined irrigation ditches before reaching the reservoir. The TMDL calculations are based on the "minimum pool" staff gage level of 45 feet, required to be maintained by agreement between STPUD and Alpine County, which corresponds to a reservoir volume of 1515 acre feet and a surface area of 110 acres.

The headwaters of Indian Creek are in U.S. Forest Service ownership. Private lands tributary to Indian Creek and to the ditches are used for livestock grazing. Vegetation in the watershed includes forest and chaparral in addition to pasture. The U.S. Bureau of Land Management owns the land immediately surrounding the reservoir and operates a campground and day use facilities, including two boat ramps. Recent recreational use figures are not available, but during the 1970s there were 50,000-70,000 visitor days of use per year. Under an agreement with Alpine County, STPUD provides funds annually to stock the reservoir with trout. It is a popular year-round fishery and provides the county with important tourism-related income.

The reservoir and the surrounding area provide wildlife habitat. Snowfree meadows in the area are deer winter range an provide a migration route for the East Carson deer heard. Bald eagles are seasonal visitors to nearby Stevens Lake. A number of sensitive plant and animal species, including the bald eagle, are potentially present in the reservoir area, but in approving a permit for Harvey Place Reservoir, north of

Indian Creek Reservoir, the U.S. Army Corps of Engineers concluded in 1985 that construction there would not affect any threatened or endangered species or their critical habitat.

A number of different trout species have been planted in Indian Creek Reservoir in the past, including the threatened Lahontan cutthroat trout. As of 1998, the Eagle Lake strain of rainbow trout, which is tolerant of alkaline conditions, was being stocked in the reservoir. Monitoring in 1998-1999 showed that Indian Creek reservoir stratifies during the summer, and that dissolved oxygen depletion occurs. Violations of the Regional Board's dissolved oxygen objective occurred during the summer of 1999. A fish kill, including both trout and native nongame fish, occurred in June 1999.

Alpine County has the smallest resident population of any county in California. The U.S. Census Bureau estimated the 1999 population for the County as a whole at 1161. About half of these people live in the Carson River watershed, in or near the small unincorporated communities of Markleeville, Woodfords, Paynesville, and Fredericksburg. Most of the Carson River watershed is in public ownership, and watershed "users" include thousands of summer and winter recreational visitors in addition to the resident population. Recreation and government employment are the most important components of the Carson River watershed's economy in California; agriculture and logging are important on a smaller scale.

The Indian Creek Reservoir area is rich in cultural resources. The U.S. Army Corps of Engineers reported in 1985 that there were 25 archaeological and 2 historical sites in the Harvey Place Reservoir area.

Section 21092.6 of CEQA requires lead agencies to disclose whether a project site is on a list of sites affected by hazardous substances (the "Cortese List") which is required to be maintained under Government Code Section 65962.5. Regional Board staff consulted with Alpine County health department staff regarding this matter, and determined that there are no "Cortese List" sites with in the Indian Creek Reservoir watershed.

ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS

Environmental Impacts. The adoption of Basin Plan amendments to incorporate TMDLs and a TMDL implementation plan for Indian Creek Reservoir will not in itself have direct adverse environmental impacts (defined under CEQA as physical effects on the environment). However, implementation of the TMDLs will involve projects which will have physical environmental impacts. The precise nature, location, and significance of these impacts cannot be determined at this time, since the implementation program establishes a process for identifying subsequent projects rather than specifying particular remedial projects in specific locations. Further CEQA or NEPA documents will be required for specific implementation projects. Overall, the long term impacts of implementing the TMDL on water quality and aquatic life and recreational uses of water will be beneficial. The environmental checklist below identifies some potential *indirect* physical impacts of the Basin Plan amendments. "Yes" and "Maybe" answers to the Environmental Checklist questions below are discussed immediately below the question they pertain to.

ENVIRONMENTAL CHECKLIST

I. LAND USE AND PLANNING- *Would the proposal:*	***YES***	***MAYBE***	***NO***
a. Conflict with General Plan designation or zoning?			x
b. Conflict with applicable environmental plans or policies adopted by agencies with jurisdiction over the project?			x
c. Be incompatible with existing land use in the vicinity?			x
d. Affect agricultural resources or operations (e.g., impact to soils or farmlands, or impacts from incompatible land uses?		x	
e. Disrupt or divide the physical arrangement of an established community (including a low-income or minority community)?			x

Reduction of nonpoint source phosphorus loads from pasture lands and irrigation ditches could require changes in agricultural operations (Id.), for example changes in grazing management practices or irrigation management practices.

II. POPULATION AND HOUSING- *Would the proposal:*	***YES***	***MAYBE***	***NO***
a. Cumulatively exceed official regional or local population projections?			x
b. Induce substantial growth in an area either directly or indirectly (e.g., through projects in an undeveloped area or extension of major infrastructure?			x
c. Displace existing housing, especially affordable housing?			x
III. GEOLOGIC PROBLEMS: *Would the proposal result in or expose people to potential impacts involving:*	***YES***	***MAYBE***	***NO***
a. Fault rupture?			x
b. Seismic ground shaking?			x
c. Seismic ground failure, including liquefaction?			x
d Seiche, tsunami, or volcanic hazard?			x
e. Landslides or mudflows?			x
f. Erosion, changes in topography or unstable soil conditions from excavation, grading, or fill?		x	
g. Subsidence of land?			x
h. Expansive soils?			x
i. Unique geologic or physical features?			x

Dredging Indian Creek Reservoir to control internal phosphorus loading would deepen the reservoir somewhat. Grading for installation of Best Management Practices could temporarily increase the risk of erosion; however, in approving waste discharge requirements or waivers for BMP projects, the Regional Board would require the use of temporary BMPs to minimize this risk.

IV. WATER- *Would the proposal result in:*	***YES***	***MAYBE***	***NO***
a. Change in absorption rates, drainage patterns, or the rate and amount of surface runoff?	x		
b. Exposure of people or property to water related hazards such as flooding?		x	
c. Discharge into surface waters or other alteration of surface water quality (e.g., temperature, dissolved oxygen or turbidity?	x		
d. Changes in the amount of surface water in any water body?		x	
e. Changes in currents, or the course or direction of water movements?		x	
f. Change in the quantity of ground waters, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations or through substantial loss of groundwater recharge capability?		x	
g. Altered direction or rate of flow of groundwater?		x	
h. Impacts to groundwater quality?		x	
i. Substantial reduction in the amount of groundwater otherwise available for public water supplies?		x	

Most of the questions in Section IV above are answered "yes or "maybe". The purpose of the TMDLs is to change (improve) water quality in Indian Creek Reservoir (Question IVc). Achieving this improvement may involve changes in drainage and runoff patterns and water movements (IVa and IVe), changes in the amounts of water present in Indian Creek Reservoir and the tributary ditch system at certain times of the year (IVd), or groundwater withdrawals to provide increased water for the reservoir (IV f, IVg). Depending on the amount of water withdrawn, this pumping could affect the direction and rate of flow of groundwater, and locally available groundwater supplies (IVg and IVi). Changes in drainage patterns, and increased evapotranspiration by riparian vegetation, could change the amounts and/or direction of flow of surface and ground waters (IVc, e and f). Infiltration of surface runoff might have local impacts on ground water quality (Question IVh). Ground water quality might also be affected by in-lake restoration activities (IVh), although the information reviewed in the technical staff report indicates that seepage to or from ICR is minimal. The application of BMPs in the upper Indian Creek watershed and in the vicinity of the ditch system will improve water quality in these tributaries.

V. AIR QUALITY- *Would the proposal:*	***YES***	***MAYBE***	***NO***
a. Violate any air quality standard or contribute to an existing or protected air quality violation?			x
b. Expose sensitive receptors to pollutants?			x
c. Alter air movement, moisture, or temperature, or cause any change in climate?		x	
d. Create objectionable odors?		x	

If a treatment wetland is selected as part of the implementation program, it could change the local microclimate (Vc). Disturbance of the reservoir sediment during restoration activities could temporarily expose visitors to objectionable odors (Vd).

VI. TRANSPORTATION/CIRCULATION: *Would the proposal result in:*	***YES***	***MAYBE***	***NO***
a. Increased vehicle trips or traffic congestion?		x	
b. Hazards to safety from design features (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?			x
c. Inadequate emergency access or access to nearby uses?			x
d. Insufficient parking capacity onsite or offsite?			x
e. Hazards or barriers for pedestrians or bicyclists?			x
f. Conflicts with adopted policies supporting alternative transportation (e.g., bus turnouts, bicycle racks)?			x
g. Rail, waterborne, or air traffic impacts?			x

If dredging or bulldozing of phosphorus rich sediment should be selected as an implementation measure, trucks would probably be needed to carry sediment to a disposal site. (It might be possible to pump dredged slurry via a pipeline to a nearby site.) Increased truck traffic could temporarily cause congestion for recreational traffic (VIa).

VII. BIOLOGICAL RESOURCES- *Would the proposal result in impacts to:*	***YES***	***MAYBE***	***NO***
a. Endangered, threatened or rare species or their habitats (including but not limited to plants, fish, insects, animals, and birds?		x	
b. Locally designated species (e.g., heritage trees)?			*x*
c. Locally designated natural communities (e.g., oak forest, coastal habitat, etc.)?			x
d. Wetland habitat (e.g., marsh, riparian and vernal pool)?		x	
e. Wildlife dispersal or migration corridors?		x	

Some of the questions on biological resources above are answered "maybe" because construction or lake restoration activities could disturb aquatic or terrestrial habitat. Such impacts would be largely temporary. Alum treatment to inactivate phosphorus in the sediment, which is one of the most widely used lake restoration methods, raises the potential for alum toxicity to aquatic life. However, the literature indicates that if the method is used properly, biological impacts are short term. There are less toxic alternatives to alum treatment; see Table 2. The purpose of the TMDLs is to provide for long term improvements in aquatic habitat in the reservoir. To the extent that they increase amounts of wetland or riparian vegetation in the watershed, nonpoint source controls will also be beneficial to wildlife.

VIII. ENERGY AND MINERAL RESOURCES- *Would the proposal*:	***YES***	***MAYBE***	***NO***
a. Conflict with adopted energy conservation plans?			x
b. Use nonrenewable resources in a wasteful and inefficient manner?			x
c. Result in the loss of availability of a known mineral resource that would be of future value to the region and the residents of the State?			x

IX. HAZARDS- *Would the proposal involve*:	***YES***	***MAYBE***	***NO***
a. A risk of accidental explosion or release of hazardous substances (including, but not limited to, oil, pesticides, chemicals, or radiation)?			x
b. Possible interference with an emergency response plan or emergency evacuation plan?			x
c. The creation of any health hazard or potential health hazard?		x	
d. Exposure of people to existing sources of potential health hazards?			x
e. Increased fire hazard in areas with flammable brush, grass, or trees?			x

If a wetland should be created to treat the tributary inflow to Indian Creek Reservoir, increased mosquito habitat could be a concern (IXc.). However, the wetland is unlikely to be near the campground and day use facilities, and impacts on recreational users of the reservoir would probably not be significant.

X. NOISE- *Would the proposal result in:*	***YES***	***MAYBE***	***NO***
a. Increases in existing noise levels?		x	
b. Exposure of people to severe noise levels?		x	

There may be temporary increases in noise associated with construction activities for implementation of the TMDLs.

XI. PUBLIC SERVICES- *Would the proposal have an effect upon, or result in a need for new or altered government services in any of the following areas:*	***YES***	***MAYBE***	***NO***
a. Fire protection?			x
b. Police protection?			x
c. Schools?			x
d. Maintenance of public facilities, including roads?		x	
e. Other government services?		x	

Implementation of the TMDLs could involve installation of Best Management Practices (BMPs) to control erosion and stormwater loading of phosphorus to Indian Creek Reservoir from public lands. These BMPs will require maintenance (Checklist Question XId). Regional Board staff resource needs will increase as a result of the needs to coordinate implementation of the TMDLs, to evaluate monitoring data, and perhaps to revise the TMDLs and implementation program in the future (XIe).

XII. UTILITIES AND SERVICE SYSTEMS. *Would the proposal result in a need for new systems or supplies, or substantial alterations to the following utilities:*	***YES***	***MAYBE***	***NO***
a. Power or natural gas?		x	
b. Communications systems?			x
c. Local or regional water treatment or distribution facilities?		x	
d. Sewer or septic tanks?			x
e. Storm water drainage?		x	
f. Solid waste disposal?		x	
g. Local or regional water supplies?		x	

Implementation of the TMDLs could affect utilities and service systems in several ways. If a new well is constructed to supply water to the reservoir, power would be needed for water pumping (Question XIIa).

If the reservoir is dredged to remove phosphorus rich sediment, a disposal site for that sediment will need to be located (XIIf). Implementation could involve changes to agricultural water distribution facilities (XIIc) and stormwater controls (XIIe). A new well could change local water supplies (XIIg).
Bank stabilization of irrigation ditches which convey water to ICR would constitute a change in water distribution facilities (Question XIIc), but this would be considered beneficial. Construction of storm drainage facilities for unpaved roads could also be beneficial to the environment (Question XIId).

XIII. AESTHETICS- *Would the proposal:*	***YES***	***MAYBE***	***NO***
a. Affect a scenic vista or scenic highway?		x	
b. Have a demonstrable negative aesthetic effect?			x
c. Create light or glare?			x

The installation of structural or vegetative Best Management Practices could change views of the Indian Creek watershed from State Highway 89, or of the reservoir from its watershed. In general, stabilization of eroding areas and increases in riparian vegetation would probably be aesthetic improvements.

XIV. CULTURAL RESOURCES- *Would the proposal:*	***YES***	***MAYBE***	***NO***
a. Disturb paleontological resources?			x
b. Disturb archaeological resources?		x	
c. Have the potential to cause a physical change which would affect unique ethnic cultural values?			x
d. Restrict existing religious or sacred uses within the potential impact area?			x

As indicated in the discussion of the Environmental Setting, the reservoir area is rich in cultural resources. Undiscovered resources could be discovered during implementation of the TMDLs. Appropriate documentation and mitigation would be provided as required under CEQA and/or NEPA.

XV. RECREATION- *Would the proposal*:	***YES***	***MAYBE***	***NO***
a. Increase the demand for neighborhood or regional parks or other recreational facilities?			x
b. Affect existing recreational opportunities?		x	

Installation of Best Management Practices near Indian Creek Reservoir, or lake restoration activities such as dredging or phosphorus inactivation, could temporarily affect recreational use of the lake (XVb). In the long term, improved water quality, and reduced erosion along the shoreline, should improve the quality of the recreational experience.

XVI. MANDATORY FINDINGS OF SIGNIFICANCE:	***YES***	***MAYBE***	***NO***
a. Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?		x	
b. Does the project have the potential to achieve short-term, to the disadvantage of long-term, environmental goals?			x

	YES	*MAYBE*	*NO*
c. Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.)			x
d. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?			x

Adoption of the proposed Basin Plan amendments will not in itself cause physical changes in or have significant impacts on the environment. Implementation of the TMDLs may have physical impacts on the environment, but the exact nature and significance of these impacts is speculative at this time.
The physical environmental impacts of a specific implementation project would occur cumulatively with those of existing watershed disturbance, and those of other implementation projects.(Question XVIc). Separate CEQA or NEPA environmental documents will be required to analyze and provide mitigation for implementation projects which have the potential for significant environmental impacts.

Determination. On the basis of this initial evaluation:

I find that the proposed project COULD NOT have a significant impact on the environment, and the functional equivalent of a NEGATIVE DECLARATION will be prepared.

I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures included in the project description have been added to the project. The functional equivalent of a MITIGATED NEGATIVE DECLARATION will be prepared.

I find that the proposed project may have a significant impact on the environment, and the functional equivalent of an ENVIRONMENTAL IMPACT REPORT is required. __x

______________________________ ______________________________

Date **Robert S. Dodds**
Assistant Executive Officer

Socioeconomic Impacts. Sections 21159 and 21159.4 of CEQA require Regional Boards, when adopting requirements for the installation of new pollution control equipment, or new performance standards for pollution control, to analyze reasonable means of compliance with the new regulations, including general consideration of environmental impacts, alternatives, and mitigation measures. The California Water Code (Section 13141) also requires discussion of costs of and financing sources for agricultural water quality control programs. As summarized below and in Appendix 1, and assuming the use of dredging, the maximum estimated cost of implementing the Indian Creek Reservoir TMDL is about $1.54 million.

Measures to reduce external loading. Possible Best Management Practices (BMPs) to reduce external loading of phosphorus to Indian Creek Reservoir could include, but are not necessarily limited to, changes in grazing management practices, stabilization of unlined irrigation ditches, stabilization of unvegetated reservoir shorezone areas, pavement of an unpaved boat ramp and parking area, and pavement of an unpaved road near the reservoir. To the extent that BMPs may need to be applied to the irrigation ditch that supplies water to ICR, and to the agricultural lands tributary to the ditch, the TMDL implementation program may be regarded as an agricultural control program. Unit costs of some BMPs which might be used to control external loading to ICR are summarized in Table 1. In order to estimate the total cost of controls for external sources of phosphorus loading, Regional Board staff assumed the use of specific BMPs for specific problem areas and, using the methods summarized in Table 1, obtained a estimated total cost of $645,592. (Of this amount, $395,592 is for agricultural sources and $250,000 is for non-agricultural sources.)

Guidance and technical advice on choosing and designing BMPs are available from Regional Board staff and through sources such as Resource Conservation Districts and the U.S. Natural Resource Conservation Service. Potential funding sources for BMPs include Section 319 grant funding to the Alpine Resource Conservation District, cost sharing through the U.S. Natural Resources Conservation Service's EQIP program, and other sources identified in the online USEPA (1999) and The Habitat Group (1999) references identified in the bibliography.

Implementation of BMPs for agricultural nonpoint sources elsewhere has had economic benefits including improvement of property values, increased streamflow or groundwater supplies, and reductions in ongoing maintenance costs (e.g., for irrigation ditches). When assessment of control needs has been completed, RWQCB staff will work with landowners and other stakeholders such as the Resource Conservation District and the Natural Resources Conservation Service to facilitate technical assistance and/or grant funding for installation of nonpoint source controls where appropriate. Volunteer labor has been used for willow planting and watershed restoration in other parts of the Carson River watershed in a series of successful annual "Conserve the Carson Days". Other potential sources of volunteer labor are flyfishing groups such as Trout Unlimited. Convict labor may also be available.

<u>Measures to reduce internal loading.</u> Table 2 summarizes the results of a scientific literature review on potential means of reducing internal phosphorus loading to ICR from the sediment. The literature review indicates that the two most promising methods for control of internal loading are dredging to remove phosphorus and alum treatment to inactivate phosphorus. Welch and Cooke (1995) cite average alum treatment costs of about $700/hectare (ha), and dredging about $20,000/ha. The area of Indian Creek Reservoir, at the "minimum pool" lake level, is 44.5 ha. The total cost of dredging could be $890,000; the total cost of two alum treatments before the 2024 deadline for attainment of the TMDL target could be $62,300. While initial dredging costs are almost 30 times those of alum treatment, the difference is much less if viewed over the long term. An alum treatment lasts about 10-20 years; dredging lasts about 50. (The tributary inflow to ICR has a low sediment concentration, and application of BMPs should minimize sediment inflow from direct surface runoff. Therefore, dredging might be effective for even longer than 50 years.)

Grant funds, including California Proposition 13 bond funds, Section 319 grant funds, or low cost loans under the Nonpoint Source State Revolving Fund, may be available to cover some of the lake restoration costs. Two online summaries of grant funding sources are referenced in the discussion of BMP costs above. The initial cost of installing BMPs may also be offset to some extent by lower maintenance costs for the affected irrigation facilities.

<u>Other socioeconomic impacts.</u> In addition to the costs to responsible parties for implementation, there will be ongoing demands on Regional Board staff time for oversight of the implementation program.
The long-term reduction of eutrophic conditions (algae and macrophyte blooms, etc.) and improvement of trout habitat will improve the recreational experience for users of Indian Creek Reservoir and will indirectly provide ongoing (and perhaps) increased economic benefits to Alpine County businesses which depend on tourism.

Regional Board staff will seek to facilitate grant funding for nonpoint source controls and lake restoration activities. The probability of funding for implementation of the Indian Creek Reservoir TMDL is higher than for some other watersheds in California because the Carson River watershed is a priority watershed in the Regional Board's "Watershed Management Initiative" and because the high degree of stakeholder involvement in watershed planning in the Carson River watershed as a whole has recently resulted in its designation as a "National Showcase Watershed" under the federal Clean Water Action Plan.

ALTERNATIVES

Environmental Impact Reports must discuss alternatives which would mitigate the significant impacts of the proposed action. The adoption of Basin Plan amendments will not have direct significant environmental impacts (defined as physical changes in the environment), and the indirect impacts are speculative at this time. The following alternatives to the proposed action could be considered:

1. ***No project.*** Basin Plan amendments to incorporate the TMDL and implementation program would not be adopted. The current management program for Indian Creek Reservoir and its tributary inflow would continue. Implementation of BMPs would eventually be required for control of surface runoff to ICR and to the tributary inflow under the statewide Nonpoint Source Plan, and this could lead to some improvement in the water quality of Indian Creek Reservoir. However, without control of internal loading, ICR would be expect to remain eutrophic, and violations of water quality objectives and impairment of aquatic life and recreational uses would continue. The federal Clean Water Act requires the USEPA to develop and adopt TMDLs for Section 303(d) listed water bodies if states do not do so. If the Regional Board does not adopt the proposed Basin Plan amendments, the USEPA will eventually adopt TMDLs. Under revisions to the federal TMDL regulations which are scheduled to take effect in October 2001, the USEPA would also adopt an implementation program. Thus, the "no action" alternative could eventually lead to federal, rather than state, requirements for implementation projects with environmental impacts similar to those discussed above.

2. More stringent targets and load allocations. The proposed Basin Plan amendments set limits which if attained, will result in mesotrophic rather than eutrophic conditions. While mesotrophic conditions should provide an adequate level of protection for aquatic life and recreational uses, they are not ideal for a trout fishery. The Regional Board could set the target phosphorus concentration in the water column at 0.01 rather than 0.02 mg/L (at the oligotrophic/mesotrophic threshold rather than the mesotrophic eutrophic threshold). However, attainment of this target is probably not feasible since background water quality in the West Fork Carson River before it is diverted to the tributary inflow is 0.02 mg/L.

3. More regulatory approach toward implementation at the outset. The proposed amendments begin at Tier 1 (self-determined implementation) of the three-tiered approach to nonpoint source control in the statewide Nonpoint Source Plan. The amendments could be structured to begin implementation of remedial water quality controls at Tier 2 (which could involve issuing conditional waivers of waste discharge requirements) or Tier 3 (involving waste discharge requirements, NPDES permits or enforcement orders). The regulatory approach could hasten implementation and ensure more rapid improvements in water quality and beneficial uses.

CEQA requires lead agencies to identify the environmentally superior alternative if it is not the proposed action. Alternative 2 would require better water quality than the proposed action, but is probably not technically feasible. Alternative 3 could result in more rapid improvements in water quality and beneficial uses than the proposed action, and should be considered the environmentally superior alternative.

CEQA requires lead agencies to discuss alternatives to "reasonable means of compliance" with new pollution control requirements. The proposed Basin Plan amendments do not specify the means of compliance (specific BMPs or lake restoration methods), but set up a process for identification and implementation of controls by stakeholders. Potential alternative control measures include, but are not limited to the measures summarized in Tables 1 and 2.

MITIGATION

The proposed action will not have any direct adverse environmental impacts, and its indirect impacts are speculative. Therefore, no mitigation, or mitigation monitoring, is currently required. Subsequent environmental documents prepared under CEQA or NEPA for specific implementation projects will identify site specific mitigation needs.

CEQA requires Regional Boards to identify potential means of compliance with new pollution control requirements, and to discuss impacts, alternatives and mitigation measures for these methods in a general way. "Reasonable means of compliance" with the Indian Creek Reservoir TMDL are discussed in the section on socioeconomic impacts. Their potential impacts are discussed as indirect impacts of the Basin Plan amendments in the Environmental Checklist above.

Most of these impacts will be temporary in nature and, if significant, could be mitigated by measures such as scheduling construction or lake treatment activities in the spring or fall rather than during the summer recreation season. Threats of water quality impacts related to temporary soil disturbance can be minimized through use of temporary BMPs to stabilize soil until permanent structural or vegetative BMPs take effect. Impacts on cultural resources or sensitive biological resources can be minimized by conducting pre-project surveys and providing mitigation as required under CEQA and other relevant state and federal laws and regulations.

CONTROVERSIAL ISSUES

Environmental Impact Reports must include summaries which, among other things, identify controversial issues associated with the project. The summary for this CEQA document identifies controversial issues including the need for the TMDL, the feasibility of attaining the phosphorus target and load allocations, and the socioeconomic impacts of implementation. This section provides additional information on these issues.

Need for the TMDL. During review of the March 2000 Notice of Preparation for this CEQA document, some stakeholders questioned whether, because Indian Creek Reservoir is an artificial reservoir, it is a water of the State and of the United States, and therefore whether the requirement for a TMDL applies. Other stakeholders expressed satisfaction with the current fishery and questioned whether there is really a problem. The technical staff report for the Basin Plan amendments addresses both of these issues.

Feasibility of attaining the phosphorus target and load allocations. Stakeholders have questioned whether it will be technically feasible to reduce phosphorus loading to the levels required by the TMDL. The basis for the load allocations is discussed in the technical staff report. They are based on published efficiencies of BMPs and lake treatment methods have been implemented elsewhere and which are technically feasible to implement at ICR.

Socioeconomic impacts of implementation. There has been general concern from some Alpine County stakeholders about the prospect of being required to implement BMPs on private lands, and specific concern from Alpine County stakeholders and STPUD staff about the cost of measures to control internal phosphorus loading. As noted above, whether or not a TMDL is adopted, the approved statewide Nonpoint Source Plan assumes that management practices will be implemented on public and private lands throughout California by 2013, with management practices to control agricultural sources to be implemented by 2003. Potential funding sources for BMPs and lake restoration methods are discussed in the Socioeconomic Impacts section, above.

LIST OF PREPARERS

This CEQA document was prepared by Judith Unsicker, Environmental Specialist IV (Specialist) at the RWQCB's South Lake Tahoe (SLT) office. Hannah Schembri, formerly an Environmental Specialist I at the SLT office, worked with Dr. Unsicker to collect background information and develop the TMDL. The following additional staff (in alphabetical order) were involved in determining the scope of the amendments, preparation of the 1999 preliminary draft amendments, or in review of the draft environmental document. Dr. Gina Johnston of California State University, Chico, was the peer reviewer for the earlier draft.

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(The Notice of Preparation for this environmental document was sent to a variety of federal, state, and local CEQA "trustee" agencies in addition to those listed below.)

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Alpine County Clerk's Office
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Hal Bird, STPUD
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Arthur Callen, U.S. Bureau of Land Management
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Federal Watermaster's Office
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Upper Carson River CRMP watershed planning group
Sheila Vassey, California State Water Resources Control Board
Janet Whitlock, U.S. Environmental Protection Agency, Region IX
Dave Zellmer, Alpine County Fish and Game Commission

REFERENCES

(Citation of the following documents is not meant to imply incorporation by reference into this CEQA document or into the Basin Plan amendments.)

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Table 1. Costs of Agricultural Best Management Practices (1996 dollars). Source: USDA Natural Resource Conservation Service.

Practice	**Unit Type**	**Unit Cost**
Fence, 3 wire barb	Feet	$0.48
Fence, 5 wire barb	Feet	$0.85
Filter strip	Acre	$108.00
Grassed waterway	Foot	$1.55
Grassed waterway	Acre	$810.00
Mulching	Acre	$78.00
Stream channel stabilization	Feet	$35.00
Use Exclusion	Acre	$10.33
Wetland Develop & Restoration	Acre	$500.00
Channel armoring	Feet	$60.00
Channel vegetation	Acre	$500.00
Channel vegetation	Foot	$5.00
Conservation cover	Acre	$31.25
Grade stabilization structure	Each	$1647.86
Heavy use area protection	Each	$2500.00
Irrigation system tailwater recovery	Each	$35,000.00
Log willow revetment	foot	$4.00
Nutrient and Sediment Control System	each	$15,000.00
Nutrient Management	acre	$1.75
Pasture and Hayland Management	acre	$13.00
Pond	each	$2700.00
Pond sealing- compacted earth	sq. foot	$0.41
Pond sealing- Hyphalon	sq. foot	$0.82
Rock riprap, Placed	cu yd	$35.00
Sediment basin	each	$1415.00
Stock Water Development	each	$1166.67
Straw Mulching	acre	$40.00
Tree revetment	foot	$15.00
Trough	each	$200.00
Vegetative cover	acre	$33.50
Waste storage facility	cu yd	$1.98
Well, livestock , 6"	foot	$22.00

Appendix 1

Background for Estimated Costs of Implementation

Introduction

The following is a summary of the assumptions made in estimating the total costs of implementation of the Indian Creek Reservoir TMDL presented in the body of the draft Environmental Document. These should be regarded as very rough estimates. In particular, field surveys have not yet been made to determine the exact locations and areas of sites needing Best Management Practices (BMPs), and specific BMPs for these sites have not yet been identified.

Implementation to Control External Sources of Phosphorus

Precipitation. No reduction is assumed in phosphorus loading from direct precipitation on the reservoir surface, and no implementation cost is involved.

Direct Surface Runoff. The estimated area needing BMPs includes the mostly unvegetated shoreline between the maximum reservoir level and the "minimum pool" level (50 acres), and an additional 20 acres including the unpaved boat ramp and parking area, the campground, and miscellaneous disturbed area in the watershed. The unpaved road is assumed to be two lanes wide and about 1 mile long in the segment which contributes runoff to the reservoir.

The Oregon Department of Transportation estimates paving costs for a two lane roadway at $100,000-$200,000 mile. Taking the average of these figures gives a cost of $150,000 to pave the road. Assuming that a two lane road covers about 5 acres, the cost per acre is $30,000. The total disturbed area for the unpaved boat ramp and parking and the campground is estimated at 3 acres; paving this area could cost $90,000. (It would be desirable from a recreational/aesthetic point of view to stabilize most of this area through means other than paving; due to the expense of paving, the $90,000 estimate is assumed to more than cover the cost of paving a smaller area and using other vegetative/structural BMPs.) Since the road is "downwind" from the reservoir and probably contributes more P from water erosion than wind erosion, graveling the road and providing storm drainage controls might be feasible and less expensive than paving; however, paving is assumed in order to provide a maximum cost estimate.

Cost estimates from the U.S. Natural Resource Conservation Service for revegetation which might apply to the shoreline of ICR range from $500/acre for wetland development and restoration to $64.43 for pasture planting to $33.50/acre for "vegetative cover" to $70.50 for a "buffer strip". Assuming that the relatively expensive hydrologic changes and grading needed for wetland development will not be involved, but that the revegetation will involve more than grasses and will therefore be more expensive than pasture, a cost of $100/acre for the shorezone revegetation is assumed. For 50 acres, the total revegetation cost would be $5,000. There are at least two steep eroding areas which may require some type of revetment; at $2500 each for a log/willow revetment the cost would be $5000.

The estimated total cost of BMPs for direct surface runoff is thus:

Pave unpaved road	$150,000
Stabilize other traffic areas	90,000
Stabilize eroding shorezone areas	5,000
Revegetate shoreline	5,000
Total	**$250,000**

Tributary inflow. By visual inspection of topographic section boundaries in relation to the land use data in Figure 4 of the environmental document, there are about two topographic sections of agricultural land (including both "cropland and pasture" and "shrub and brush rangeland") in the watershed tributary to upper Indian Creek and the irrigation ditch system which brings water to Indian Creek Reservoir. For purposes of these calculations the total area is estimated at 1200 acres. Assumptions are also made that the ditch system is four miles long, that one mile of ditch crosses agricultural lands, and that two miles of ditch need BMPs. Assuming that prescribed grazing is used on the entire agricultural area at a unit cost of $4.06/acre, the total cost of this BMP is $4,872. Stream channel stabilization for the two miles of ditch estimated to need it, at $35.00/foot of ditch, could cost $369,600. Fencing both sides of the one mile of ditch which crosses agricultural lands, assuming $2.00 a foot for barbed wire fence, could cost $21,120.

The estimated cost for implementing BMPs for the watershed contributing phosphorus via the tributary inflow is:

Prescribed grazing	$4,872
Stream channel stabilization	369,600
Fencing part of ditch	21,120
Total	**$395,592**

The total estimated cost of controlling phosphorus loading from external sources is $645,592.

Implementation to Control Internal Sources of Phosphorus

The reservoir surface area at "minimum pool" gage height is 110 acres (44.5 ha or 532,400 square yards). The sediment is about 6 inches deep; therefore the volume of sediment over entire lakebed is about 88,378 cubic yards. The volume of sediment in the 23 acre area which becomes stratified in summer is about 18,479 cubic yards.

A number of lake restoration projects in Nebraska involving dredging had an average cost of about $4.00/cubic yard of dredged material. Assuming that dredging costs have doubled due to inflation (which may or may not be the case), the cost of dredging the entire bed of ICR would be about $707,024, and the cost of dredging only the sediment in the area which stratifies would be about $147,832. Using the median dredging cost/hectare in case studies summarized by Cooke *et al*. (1993) of $17,984/ha and ICR's surface area of 44.5 ha, the cost of dredging the entire lake would be $800,388.

Welch and Cooke (1995) cite dredging costs of about $20,000/ha and alum costs of about $700/ha. Using these figures and the ICR surface area of 44.5 ha gives relative costs of $890,000 and $31,150. Assuming that alum treatment needed to be done twice before 2024, the total cost would be $62,300.

Total Cost of Implementation

Assuming the use of dredging to control internal loading, the total cost of controlling external and internal phosphorus loading at ICR could be as high as $1.54 million. Assuming the use of alum or other chemical inactivation, the total cost could be $708,000.

Table 2. Comparison of Alternative Lake Restoration Methods (Cooke et al., 1993 and other references cited in Table)

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Dilution and Flushing- addition of low nutrient water and/or high volume water; dilutes P concentration; washes out algal cells.	Can control internal loading, algal biomass (including bluegreens which contribute to internal loading), increase clarity. Relatively low cost if water is available; immediate and proven effectiveness if limiting nutrient decreased. Dramatic improvements in Moses Lake, WA with a 10-20 percent per day water exchange with Columbia River water (EPA, 1988).	To be effective, flushing rate must approach or equal algal growth rate, Principle limitation is availability of low nutrient water. Potential adverse impacts on downstream waters from exported nutrients.	Variable from site to site depending on availability of water and cost of installing and maintaining distribution facilities and outlet structure (Cooke et al; USEPA 1988.)	Level of dilution and flushing under current water rights/operating criteria is inadequate to prevent eutrophication. Unless "new" water can be supplied (e.g. through a well) additional dilution/flushing probably not feasible.
Hypolimnetic Withdrawal -(release of nutrient rich/oxygen poor water from bottom of lake, through siphoning, pumping, or selective release rather than release from surface)	Relatively low capital and operational costs; effective in a large fraction of cases (maximum TP decreased; depth and duration of hypolimnetic anoxia decreased); potential long term and permanent effectiveness in increasing dissolved oxygen, reducing internal P loading.	Effectiveness depends on frequent interchanges of hypolimnetic water (several fold during the stratification period). Three to 5 years of total P export may be necessary to see an improvement in epilimnion quality. Potential adverse impacts on downstream water quality and uses from exported waters (with low DO, high P, and possibly high ammonia, hydrogen sulfide, and metals). Nuisance odor conditions may also occur.	Installation costs, (In 1990 dollars); for a 41 ha lake with 3.4 cubic meters/minute flow, $304,000; for a 287 ha lake with 6.3 cubic meters/minute flow- $45,000. (Indian Creek reservoir has a surface area of about 65 ha.)	Current water rights situation and operating criteria for ICR would not allow substantial releases of anoxic water during the summer when the reservoir is stratified..
Hypolimnetic aeration or oxygenation- Addition of compressed air or pure oxygen to bottom waters of lake during stratification.	Raises oxygen concentration without destratifying the water column or warming the hypolimnion; provides increased habitat and food for cold water fish; can reduce internal loading of P, NH4+, Mn, and Fe.	Effectiveness depends on proper design and sizing in relation to oxygen demand. May increase eddy diffusion of nutrients to epilimnion even if stratification is maintained. Works best for deeper waters (over 12-15 meters). Needs a large hypolimnion to work properly; use in shallow lakes and reservoirs should be viewed with caution (USEPA, 1988).	Dependent on equipment costs, power rates, cost of compressed air. In one case study, initial aeration cost was $6500/ha for 6 months operation ($3.40/kgO2). Another case study had a cost of $2.50 /kg02. Long term costs (mostly operational) considered "relatively modest".	"Aerators" used at ICR did not add oxygen; see artificial circulation below.

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Artificial circulation (destratification)- injection of compressed air, or mechanical mixing devices	Enlarges habitat for aerobic animals; may reduce internal loading of P and decrease biomass of algae (especially blue-greens). Artificial destratification using bubble plumes reduced internal P loading in Chaffey Reservoir, Australia by about 85%. (Sherman, 1999).	Highly variable results from case to case (USEPA, 1988). Depending on sediment chemistry, may increase internal P loading. Temperature increase in hypolimnion may adversely affect cold water fish. Efficiency depends on air flow rate, depth at which air is released.	\$340-\$460/ha (1990 dollars) for installation and 1 year operation; annual costs \$320/ha (1990 dollars).	"Aerators" used for years at ICR to prevent winter ice formation; apparently did not prevent summer stratification / oxygen depletion.
Phosphorus Removal (Dredging or Drawdown and Scraping)	Rapid, long term decrease in internal nutrient loading and nutrient concentration in water column. Compared to P inactivation, does not introduce a "foreign" substance to the lake.	Must consider disposal site for dredged sediment and prevention of runoff from disposed sediment to surface waters, and sedimentation rate from external sources. Dredging can resuspend nutrients and toxic substances if present in sediment, create temporary odor problems (e.g. hydrogen sulfide), temporarily disrupt recreational uses, have temporary impacts on benthic biota. Drawdown and bulldozing could also temporarily affect recreational and benthic habitat uses and have temporary noise, dust, and traffic impacts.	(Cooke et al 1993) Median costs in 1991 dollars based on 9 case studies: \$ 17,984/ ha. Costs are lower if amortized over years of effectiveness; e.g., Lake Trummen, Sweden had an initial dredging cost of about \$5722/ha; the amortized cost over 25 years was \$229/ha/yr.	ICR probably has relatively low external sediment loading. which can be further reduced through BMPs. ICR sediment is fairly shallow (~6 inches in ___) compared to some lakes which have been dredged for restoration. Cooke et al identify dredging as the most reliable and permanent (although costly) solution to internal P loading if most nutrients are located in the top 0.3-0.5 meter of a sediment core.
Phosphorus Inactivation Using Alum Aluminum salts added to water, and produce a floc which precipitates P in the water column, then settles and provides a barrier to P release from the sediment..	Widely used; many case studies of effectiveness. Rapid, fairly long term (at least 10-15 years) decrease in internal nutrient loading and nutrient concentration in water column; increased transparency, reduced algal biomass. (USEPA 1988). Reduced P release up to 90 percent in laboratory experiments. Can reduce P loading from groundwater seepage as well as from internal recycling (Harper and Harvey, 1999). Sufficient floc may bury resting stages of benthic algal mats and limit future mat formation (Wagner et al, 1999). Apparent low or zero toxicity to aquatic biota with properly buffered applications.	Effects can be negated by high external nutrient loading and/or sedimentation which buries floc layer. If floc layer is too thin, benthic invertebrates can mix it with sediment, reducing effectiveness (Charboneau, 1999). Without adequate buffering (outside pH range of 6-8) , aluminum salts may be toxic . Less effective at removing organic P than inorganic P from water column. Temporary disturbance of recreational uses. Increased transparency may promote macrophyte spread (USEPA 1988).	Median cost of 9 case studies = \$564 ha.(1991 dollars) Cooke *et al.* cite amortized cost of one project which lasted 16 years as \$26.56/ha.	

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Phosphorus Inactivation Using Iron. Similar effects to those of alum, above.	Less concern about biotic impacts than for alum	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage.. Effects can be negated by high external nutrient loading. Would need to use aeration or artificial circulation (complete mixing) to maintain needed redox and pH conditions.		
Phosphorus Inactivation Using Calcium. Similar effect to those of alum, above.	Less concern about biotic impacts than for alum	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage. Effects can be negated by high external nutrient loading. May need to maintain alkaline pH to maintain effectiveness; would need aeration or complete mixing on a continual basis. .		
Phosphorus Inactivation using "Riplox" process. (Oxidation of top 10-20 cm of sediment through enhanced denitrification, improves P complexation with iron; prevents sulfate reduction)	Reduced sediment P release up to 90 percent in laboratory experiments; 50-80 percent reductions in lake case studies. Uses chemicals normally found in sediments; chemicals are placed directly in and largely confined to sediments. May last longer than alum treatment.	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage. Effects can be negated by high external nutrient loading. Assumes internal P loading due to iron redox reactions; if due rather to temperature and pH may not provide significant reduction. Chemicals must be applied with a special "harrow" device.	$5200/ha (1990 dollars). (Early case studies used experimental procedures.)	ICR sediment is relatively shallow (~6 inches, within cited 10-20 cm range of effectiveness of method.)

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Biomanipulation -Food web management (restructuring fish communities) to control algae.		Experimental; many interactions poorly understood, particularly in connection with small europhic lakes. (Such lakes may have significant macrophyte communities) Less precise than mechanical or chemical controls and requires knowledge of food web processes, which can be complex. May have unforeseen ecological consequences. Herbivores encouraged by food web changes may not be able to deal with filamentous bluegreen algae like those present at ICR	Depends on means used to change fish community/control existing fish (drawdown, rotenone, netting, etc.) . Manipulation may be required on a permanent basis in order to make effects last.	Available case studies (mostly eastern U.S. and Europe) do not involve the fish species present in ICR.
Periphyton management- Nutrient rich water to grow attached algae as it flows over a substrate; algae are harvested to remove nutrients from system.	Relatively "low tech"; high nutrient removal efficiency under certain circumstances. (DeBusk et al., undated).	Would require maintenance; presence of structures at ICR could detract from recreational experience; efficiency under conditions at ICR not known; disposal site would be needed for algae/nutrients.		
"Pretreatment"- Use of wetlands,detention basins or upstream reservoirs to remove nutrients in inflow to lakes/reservoirs.	Reduces external loading; wet detention basins provide 47-68% removal of total P. Wetlands- up to 83 % removal of P. Jordanelle Reservoir on Provo River, UT reduced downtream P by about 25% (Miller and Cutler, 1999).	Would not address internal loading at ICR. Wetlands may release P at certain times of year. Treatment facilities could require maintenance such as sediment removal from basin, harvesting of vegetation from wetland.	Depends on size and maintenance requirements.	

DRAFT

TECHNICAL STAFF REPORT:

TOTAL MAXIMUM DAILY LOAD AND IMPLEMENTATION PLAN

INDIAN CREEK RESERVOIR, ALPINE COUNTY, CALIFORNIA

California Regional Water Quality Control Board
Lahontan Region
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Section 1. Executive Summary

Indian Creek Reservoir (ICR), located in the Carson River watershed in Alpine County, was constructed to store treated wastewater exported from the South Lake Tahoe area for later use in pasture irrigation, and to serve as a recreational fishery. The reservoir was placed on the list of impaired water bodies required under Section 303(d) of the federal Clean Water Act, due to eutrophication. Development of Total Maximum Daily Loads (TMDLs), and TMDL implementation plans, is required for Section 303(d) listed water bodies under federal and state regulations. The California Regional Water Quality Control Board, Lahontan Region (Regional Board) has developed a TMDL for total phosphorus loading to ICR, since phosphorus is believed to be the controlling nutrient for the eutrophication process.

TMDLs are strategies to ensure the attainment of water quality standards. By definition, the "Total Maximum Daily Load" of a pollutant which can be allowed if standards are to be attained is equivalent to the sum of "wasteload allocations" for point sources of pollutants, "load allocations" for nonpoint sources, and an explicit or implicit margin of safety to allow for uncertainty in the analysis.

The Regional Board's) TMDL for ICR identifies load allocations for total phosphorus which, when implemented, are expected to result in the attainment of applicable water quality objectives and the protection of beneficial uses. The beneficial uses of concern are aquatic habitat and recreation uses. The Regional Board is also considering adoption of a TMDL implementation program. Both the TMDL and the implementation program have been substantially revised as a result of comments by U.S. Environmental Protection Agency (USEPA) and State Water Resources Control Board (SWRCB) staff, and by a scientific peer reviewer, on earlier drafts.

The TMDL and implementation program will be considered for adoption as amendments to the Regional Board's *Water Quality Control Plan for the Lahontan Region* (Basin Plan). This staff report summarizes the technical background for the proposed amendments. More detailed technical information will be included in the administrative record of the Basin Plan amendment process.

Components of the TMDL

The TMDL includes:

- A problem statement
- Numeric targets
- Source analysis
- Linkage analysis
- Load Allocations, and
- Discussion of the margin of safety and seasonal and annual variation.

The TMDL implementation program includes:

- A process and schedule for selection and implementation of controls external and internal phosphorus loading
- A monitoring program related to the numeric targets, and
- A schedule for review and revision of the TMDL.

Problem Statement. The TMDL focuses on ICR, its immediate watershed which contributes direct surface runoff, and the tributary inflow to ICR which includes the upper Indian Creek watershed and the watershed downstream of the diversion point from the West Fork Carson River. The water quality standards of concern are recreational and aquatic life beneficial uses, and narrative objectives for parameters such as dissolved oxygen, pH, and biostimulatory substances. A literature review shows that the existing numerical water quality objective for phosphorus, which was established when ICR was receiving wastewater, is at a level which will promote eutrophication even if it is attained. More than 11 years after the diversion of wastewater and the addition of fresh water which provides some dilution, ICR continues to show symptoms of eutrophication including high concentrations of total phosphorus (1999 mean concentration 0.08 mg/L), summer depletion of dissolved oxygen to near-zero levels in the hypolimnion, low summer transparency, and blooms of blue-green algae.

Numeric targets. The primary TMDL indicator/target is a mean annual total phosphorus concentration in ICR of 0.02 mg/L, which the literature indicates will promote mesotrophic, rather than eutrophic conditions, and will thus protect beneficial uses. Additional numeric targets and indicators, related to eutrophication and beneficial use support, have been selected. The targets and indicators are summarized in Table 3.

Source analysis. Regional Board staff used monitoring data and reports from the South Tahoe Public Utility District (STPUD) and its consultants, simple mass balance calculations, and an equation from the literature to estimate cumulative historical phosphorus loading to ICR, and current external and internal phosphorus loading. Based on external loading from precipitation, runoff, and tributary inflow, internal loading from oxic and anoxic sediments, and the P load in the outflow, the total existing load is 468 lb/year, and the net load in the water column is 331 pounds. The source analysis is summarized in Table 9.

Loading Capacity Linkage Analysis. The loading capacity, or "total maximum daily load" which corresponds to the phosphorus concentration target is 82 pounds per year *in the water column*. (An additional allowable load will exit the reservoir in the outflow.) The linkage analysis discusses the relationship between phosphorus loading and trophic status, including the implications of internal loading of phosphorus. It provides the basis for estimating the phosphorus loading reductions necessary to attain numeric targets and protect beneficial uses. The linkage is based on concentration-response relationships between phosphorus loading and eutrophication which have been developed from empirical data from a large number of north temperate lakes.

Load allocations. There are no point sources of phosphorus in the affected watershed. Therefore, the "wasteload allocation" for this TMDL is zero. Load allocations are set for external (direct surface runoff, direct precipitation, tributary inflow) and internal (sediment) sources of phosphorus loading. Load allocations are based on literature figures for the efficiency of Best Management Practices (to control external loading) and of in-lake measures to remove sediment or inactivate release of phosphorus from the sediment (to control internal loading**).** Load allocations are contained in Table 12. Information on BMPs and potential in-lake phosphorus control measures is summarized in Tables 10 and 11.

Margin of Safety and Seasonal and Annual Variation. The TMDL includes an implicit margin of safety, based on conservative assumptions, to compensate for uncertainty in the analysis, and to ensure that the allocations, when achieved, will result in attainment of standards. The TMDL accounts for seasonal and annual variations by expressing external load allocations as 10 year rolling averages, to account for variability in delivery of phosphorus to ICR via surface runoff and tributary inflow, and by requiring significant reductions in internal loading from the sediment during the critical summer stratification period.

Public Participation. Public participation for the TMDL will be provided through the Regional Board's Basin Plan amendment process (which includes public review under the California Environmental Quality Act, and adoption following a noticed public hearing), and through subsequent public review periods preceding approvals of the amendments by the SWRCB and the USEPA. The SWRCB will submit the Basin Plan amendments, with supporting documentation, to the USEPA for approval as a TMDL after they have been approved by the California Office of Administrative Law.

Implementation and monitoring programs. Implementation will be the responsibility of the STPUD, which manages the reservoir and its tributary inflow; the U.S. Bureau of Land Management, which owns much of the watershed; Alpine County, which manages an unpaved road in the watershed, and other public and private landowners in the watershed of the tributary inflow. The Regional Board is precluded by the California Water Code from specifying the manner of compliance with its orders. The proposed Basin Plan amendments would establish a process under which Regional Board staff would work with responsible parties toward selection and implementation of specific Best Management Practices to control external phosphorus loading, and in-lake methods to control internal phosphorus loading. The results of a literature review on potential implementation measures to control external and internal sources of phosphorus loading are summarized in Tables 10 and 11.

The Lahontan Regional Board has authority under the Clean Water Act and the California Water Code to ensure implementation of the Indian Creek Reservoir TMDL. Initially, the Board will rely on the three-tier implementation approach outlined in the statewide *Plan for California's Nonpoint Source Pollution Control Program* (California State Water Resources Control Board, 2000). The three-tier approach begins with "self determined implementation"; the second and third tiers involve regulatory action to ensure implementation of nonpoint source controls. Implementation the TMDL for Indian Creek Reservoir is expected to occur no later than 2003 (for agricultural BMPs) and no later than 2013 for other measures. These are the deadlines set by the statewide Nonpoint Source Plan for implementation of BMPs throughout California). Attainment of standards (i.e., attainment of the total phosphorus target and improvement of ICR to mesotrophic rather than eutrophic conditions as measured by the TMDL indicators) is projected to occur by 2024. The TMDL monitoring program involves continuation of current monitoring by the STPUD of ICR and its tributary inflow.

Review and Revision of the TMDL. Regional Board staff will review monitoring reports submitted by the STPUD on an ongoing basis, and will conduct comprehensive reviews of available data every five years after final approval of the TMDL, to evaluate trends toward improvement. Since some of the targets are expressed as ten year rolling averages, any decision regarding the need to revise the TMDL will be made after the tenth year.

Section 2. Introduction

The Lahontan Regional Water Quality Control Board (Regional Board) is the California State agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Regional Boards which function as part of the California State Water Resources Control Board (SWRCB) system within the California Environmental Protection Agency. The Lahontan Regional Board implements both the federal Clean Water Act and the Porter-Cologne Water Quality Control Act, part of the California Water Code. Water quality standards and control measures for waters of the Lahontan Region are contained in the *Water Quality Control Plan for the Lahontan Region* (Basin Plan).

Under Section 303(d) of the Clean Water Act, the RWQCB is required to identify surface waters which are not meeting water quality standards and are not expected to do so even with the use of technology-based controls. For Section 303(d)-listed waters, the RWQCB must develop strategies called “Total Maximum Daily Loads” or TMDLs. TMDLs involve calculation of pollutant loads from all point and nonpoint sources in the watershed, and determination of the reductions in pollutant loads from each of these sources which, when considered together with a “margin of safety”, are necessary for attainment of standards.

Indian Creek Reservoir (ICR) was constructed on an ephemeral tributary of Indian Creek, which itself is tributary to the East Fork Carson River in Nevada. The reservoir was designed to store treated tertiary-treated domestic wastewater effluent exported by the South Tahoe Public Utility District (STPUD) from the Lake Tahoe Basin, for later use in pasture irrigation. (Export of all wastewater from the Lake Tahoe watershed has been required since the 1960s in order to protect the unique ecological and recreational values of Lake Tahoe; see Section 5.2 of the Basin Plan.) ICR was also designed to serve as a recreational trout fishery. It became eutrophic due to high levels of nutrients, and experienced problems during the 1970s and early 1980s including heavy growths of aquatic weeds, summer depletion of dissolved oxygen, fish kills from high levels of unionized ammonia, and taste and odor problems related to blue-green algae. (For definitions of "eutrophic" and other technical terms, see the Glossary at the end of this report.)

ICR was identified as a Section 303(d) impaired water body in the mid-1980s (California State Water Resources Control Board, 1988). In 1989, the STPUD ceased disposal of wastewater to ICR, and began a long term program of maintaining reservoir levels with fresh water diverted from Indian Creek and the West Fork Carson River. Although concentrations of some wastewater constituents declined, phosphorus concentrations in the water column remain high (about twice as high as the water quality objective in 1999), and the reservoir continues to exhibit symptoms of eutrophication including low transparency, summer depletion of dissolved oxygen in deeper waters, and blooms of blue-green algae. A literature review indicates that internal loading of phosphorus from the sediment is occurring. The proposed TMDL addresses both external and internal nonpoint sources of phosphorus.

This staff report summarizes the technical background for the proposed TMDL and TMDL implementation program. (The TMDL itself is the language to be incorporated into the Basin Plan through the proposed amendments.) The staff report includes a glossary of technical terms. The technical data summarized in this report will be available separately as part of the administrative record. The draft Basin Plan amendment language and an analysis of environmental and socioeconomic impacts of adoption of the amendments are contained in separate reports.

Section 3. Supporting Information for TMDL Components

This TMDL is based on monitoring data for ICR and tributary waters collected by the STPUD, on reports by STPUD's consultants, and on a review of scientific literature related to eutrophication, phosphorus cycling, and lake restoration. The STPUD maintains its own state certified laboratory. Precipitation and runoff quality data from the neighboring Lake Tahoe Basin were used to estimate some of the external phosphorus loading. Stakeholders provided information about water rights, reservoir management procedures, and land use.

The TMDL relies on the strong quantitative framework, based on a large set of empirical data, which has been developed for north temperate lakes to allow prediction of algal biomass and other water quality parameters from nutrient loading and water column nutrient concentrations (USEPA, 1999). Simple mass balance calculations were used to develop the source analysis, loading capacity and load allocations. The implementation program is based on the Regional Board's existing authority, including the three tier approach and implementation schedule set forth in the SWRCB's statewide nonpoint source control plan (California State Water Resources Control Board, 2000).

Section 3.1. Problem Statement

Indian Creek Reservoir is Section 303(d) listed for eutrophication. Since the 1970s, it has shown symptoms of eutrophication including impairment of aquatic life and recreational uses, and violation of narrative and numerical water quality objectives. While concentrations of some wastewater constituents (e.g., nitrogen and chloride) declined following the cessation of wastewater disposal to ICR in 1989, eutrophic conditions have persisted, and violations of some water quality objectives continue to occur. The TMDL focuses on control of total phosphorus loading, since a literature review indicates that phosphorus is the primary nutrient currently contributing to eutrophication. The TMDL is designed to protect beneficial uses; the literature shows that reduction of external and internal phosphorus loading should reduce biological productivity, and should lead to protection and enhancement of beneficial uses, and attainment of water quality objectives for eutrophication-related parameters other than phosphorus. (Several of the current water quality objectives were adopted when ICR was receiving wastewater and are not protective of the beneficial uses associated with a recreational trout fishery. These objectives should be revised to be more protective when resources permit.)

A. Watershed Overview

Status of ICR as a "Water of the State". During development of the TMDL, some stakeholders questioned whether ICR, as an artificial reservoir, is a water of the State and of the United States, and thus whether TMDL development is necessary. The reservoir is considered a water of the state and of the U.S. for several reasons: (1) the Clean Water Act makes no distinction between natural and man-made water bodies in determining whether a given water body is a water of the U.S.; (2) ICR is tributary to a water of the U.S.; (3) ICR was constructed on an ephemeral water of the U.S.; (4) ICR has had designated, USEPA approved water quality standards since 1975. ICR was also formerly subject to an NPDES permit.

Geographic Scope of TMDL. The TMDL addresses loading to Indian Creek Reservoir from external and internal sources. External sources include the lands, mostly under USBLM ownership, which are directly tributary to the reservoir, and the lands in the upper Indian Creek watershed tributary to the creek and to Snowshoe Thompson Ditch #1, which conveys water from the West Fork Carson River and upper Indian Creek to ICR (see Figure 2). Monitoring data show that the West Fork Carson River meets its water quality objectives for total phosphorus, which are based on natural background levels. Water which enters the conveyance system from the West Fork Carson River is considered to be "background" loading for purposes of the TMDL. No TMDL implementation is required or planned for the West Fork Carson River and its watershed upstream of the diversion point as part of the TMDL for Indian Creek Reservoir.

Location and Description. Indian Creek Reservoir is located in eastern Alpine County, California (Figures 1 and 2), at an elevation of about 5600 feet in Sections 3 and 4, T10N, R20E, MDB&M. It was constructed between 1968 and 1970, and has a main rockfill dam, 68 feet high, and a smaller saddle dam to prevent overflow into another nearby impoundment, Stevens Lake. Soils were stripped to hardpan to minimize initial amounts of organic matter in the reservoir The surface area of ICR is about 160 acres when a maximum water surface elevation of 5600 feet is reached. It is currently maintained at a lower than maximum level due to the limitations of water rights. The TMDL calculations are based on the smaller reservoir area and volume associated with the "minimum pool" gage height of 45 feet under current operating criteria. At this level, ICR has a surface area of 110 acres, a volume of 1515 acre-feet, and a mean depth of 13.7 feet.

Geology and Soils. The geology of the area near ICR includes extrusive and intrusive igneous rocks, with overlying alluvium within the valleys. Soils around ICR are stony to very stony sandy loams derived from andesitic tuff. These soils are moderately to highly erosive and relatively infertile. Soils of Diamond and Wade Valleys, downstream of ICR, include both loams and sandy loams with predominantly granitic alluvium as the parent material (Jones & Stokes Associates, 1978).

Climate and Hydrology. The mean annual precipitation at Woodfords, which was used to estimate direct surface runoff from the ICR watershed, is about 20 inches. Most precipitation falls as rain, although there is some snow; 70 percent of annual precipitation occurs between November and April. The mean annual temperature at Woodfords (elevation 5671) is about 49 degrees Fahrenheit. Water temperatures in ICR range from freezing to about 22 degrees C. in July and August. Ice cover on the reservoir is generally only partial and occurs during December and January (Lake Tahoe Area Council, 1975).

Following the cessation of wastewater disposal, fresh water for maintenance of the reservoir level was provided, via irrigation ditches, by diversions from Indian Creek and the West Fork Carson River. According to STPUD staff, the small tributary of Indian Creek on which ICR was constructed was largely inundated and does not currently provide significant flows to the reservoir. The magnitude of ground water inflow to ICR is unknown, but is considered "de minimis" for purposes of the TMDL calculations. ICR has only one outlet, which discharges ultimately to Indian Creek. The current water budget for ICR is discussed in connection with the TMDL calculations below.

Vegetation. The reservoir is located in a transition zone between Jeffrey pine and sagebrush vegetation types. Vegetation surrounding the reservoir includes sagebrush, bitterbrush and bunch grasses, with some pinyon and Jeffrey pine (Jones & Stokes Associates, 1978). Agriculture in the area involves irrigated pasture.

Fish and Wildlife: STPUD (1968) stated that Indian Creek [actually the tributary covered by ICR] before reservoir construction was intermittent and without fish. This may or may not have been the creek’s natural condition; past watershed disturbance including livestock grazing may have affected stream hydrology. Snowfree meadows in the reservoir area are deer winter range and provide a migration route for the East Carson deer herd (Jones and Stokes, 1983a). Jones & Stokes Associates (1978) include a list of animal species expected to be found in the vicinity of ICR, and stated that fish in ICR as of 1978 included rainbow trout, cutthroat trout, tui chub and speckled dace. Brook trout had formerly been planted. As of 1998, the Eagle Lake strain of rainbow trout, which is tolerant of alkaline conditions, was being stocked in the reservoir. Most of the fish that died during the June 1999 fish kill were tui chub, a native non-game fish, but the kill also included rainbow trout, Lahontan cutthroat trout, and Tahoe suckers (Stafford Lehr, California Department of Fish and Game, personal communication).

No comprehensive limnologic study of ICR has been done since the 1970s . During 1998 and 1999, Regional Board staff observed macrophytes (mostly *Elodea*) in nearshore waters. Dried *Elodea*, crusts of blue-green algae, and abundant snail shells were present along the shore during low water conditions.

Rare/Threatened/Endangered Species. Bald eagles are seasonal visitors to Stevens Lake near ICR, where they roost on snags (Jones and Stokes 1983a). The Carson River watershed historically supported the Lahontan cutthroat trout, which is now a federally threatened species. Lahontan cutthroat trout were planted in Indian Creek Reservoir in the past. Other sensitive animal species historically or potentially present in the Carson River watershed include golden eagles, prairie and American peregrine falcon, falcon, pine marten, wolverine, rubber boa, spotted bat, Sierra Nevada red fox, ferruginous hawk, western burrowing owl, and Paiute cutthroat trout. In issuing a permit for construction of Harvey Place Reservoir, which is near ICR, the U.S. Army Corps of Engineers (1985) determined that its construction would not affect any threatened or endangered species or their critical habitat.

Land Use. The U.S. Bureau of Land Management manages the land surrounding the reservoir, including campground, boat launching, and picnic facilities. The headwaters of Indian Creek are located within the Humboldt-Toiyabe National Forest; there is an unpaved road near the creek in this reach. Livestock grazing occurs on private lands in the Indian Creek watershed upstream from the reservoir. An unpaved Alpine County road provides access to an unpaved boat ramp near the dam. Water released from the reservoir is used for irrigation on private lands downstream, which are the only large area of private ownership remaining in the Carson River watershed in California. Irrigated lands in Diamond Valley are primarily used for pasture, but there is some cultivation of grass hay and alfalfa (Jones & Stokes, 1978).

Population. Alpine County has the smallest resident population of any county in California. The U.S. Census Bureau estimated the 1999 population of Alpine County as a whole at 1161. About half of these people live in the Carson River watershed, in or near the small unincorporated communities of Markleeville, Woodfords, Paynesville, and Fredericksburg. The Woodfords Indian Community is located near the main stem of Indian Creek downstream of ICR. Most of the Carson River watershed is in public ownership, and watershed “users” include thousands of summer and winter recreational visitors in addition to the resident population.

Recreation. No recent surveys have been done on visitor use at the campground and day use facilities at Indian Creek Reservoir. However, the USBLM estimated about 50,000-70,000 visitor days of use per year during the 1970s. During these surveys, fishing was reported as the primary reason for visiting ICR. The reservoir is used year-round by fishermen when access is not restricted by snow (Wood, 1978). According to Dave Zellmer of the Alpine County Fish and Game Commission (personal communication, 1998), fishing at the reservoir is still very popular and important to Alpine County’s economy. “Fishing derby” events are occasionally held at the lake.

Cultural Resources. The area near ICR is rich in cultural resources. The U.S. Army Corps of Engineers reported (1985) that there were 25 archaeological and 2 historical sites in the adjacent Harvey Place Reservoir project area.

B. Applicable Water Quality Standards

Water quality standards were initially adopted for ICR in the 1975 North Lahontan Basin Plan (California Regional Water Quality Control Board, 1975), and were updated when that plan was amended in 1983-84. California’s water quality standards include both designated beneficial uses and narrative or numerical “water quality objectives” established to protect those uses. The concept of state water quality objectives is similar to that of federal “criteria”; both are essentially levels of water quality which should not be exceeded if beneficial uses are to be protected.

The currently designated beneficial uses of ICR are Agricultural Supply, Commercial and Sportfishing, Freshwater Replenishment, Municipal and Domestic Supply, Non-contact Water Recreation, Cold Freshwater Habitat, Ground Water Recharge, Wildlife Habitat, Water Contact Recreation, and Navigation. Definitions of all of these uses can be found in Chapter 2 of the Basin Plan. The 1995 Basin Plan does not distinguish between existing and potential uses. The recreation and aquatic life uses of ICR (see Table 1) are the uses which are most affected by eutrophication.

Suggestions have been made from time to time that Indian Creek Reservoir should more appropriately be designated for the Warm Freshwater Habitat (WARM) beneficial use than for Cold Freshwater Habitat. However, the reservoir has supported cold freshwater organisms, albeit with problems, since November 28, 1975, the effective date of the USEPA water quality standards regulation, and the COLD use must therefore be considered an "existing" use which cannot be removed under those regulations. Department of Fish and Game staff (Woods, 1978) discussed the possibility of a warm water fishery alternative, but identified potential temperature problems for bass and catfish. Woods also noted that the conditions of a state Davis-Grunsky grant which was used toward construction of ICR specified maintenance of a trout fishery.

Table 1. Beneficial Uses of Indian Creek Reservoir Affected by Eutrophication

Use	Definition
Cold Freshwater Habitat (COLD)	Beneficial uses of waters that support cold water ecosystems including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Water Contact Recreation (REC-1)	Beneficial uses of waters used for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, and use of natural hot springs.
Non-contact Water Recreation (REC-2)	Beneficial uses of waters used for recreational activities involving proximity to water, but not normally involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, and aesthetic enjoyment in connection with the above activities.
Commercial and Sportfishing (COMM)	Beneficial uses of waters used for commercial or recreational collection of fish or other organisms including, but not limited to, uses involving organisms intended for human consumption.

Table 2 summarizes applicable water quality objectives. The full text of each water quality objective is contained in Chapter 3 of the Basin Plan. The statements that particular parameters "shall not be altered" were adopted during update of the Basin Plan in 1983-84, while ICR was still receiving wastewater, and apparently reflect the intent that eutrophication problems should not be allowed to worsen. If interpreted literally today, they could preclude further restoration of the reservoir and require maintenance of eutrophic conditions.

Numerical water quality objectives were established for nutrients in ICR in the 1975 Basin Plan, at the time when it was receiving wastewater. These objectives are 0.04 milligrams per liter (mg/L) for total phosphorus and 4.0 mg/L for total nitrogen. The nitrogen and phosphorus objectives were based on water quality achievable in a reservoir consisting mostly of tertiary-treated effluent, <u>not</u> on criteria for protection of beneficial uses (James Kuykendall, former Assistant Executive Officer, Lahontan Regional Board, personal communication). These objectives are much higher than “background” levels of nutrients in natural surface waters in the Carson River watershed. For example, the total phosphorus and total nitrogen objectives for the West Fork Carson River at Woodfords, which are based on historical monitoring data, are 0.02 and 0.15 mg/L, respectively.

In addition to designated beneficial uses and narrative and numeric objectives (including the nondegradation objective) five regionwide and three watershed-specific waste discharge prohibitions apply to surface waters if the Carson River watershed (see Section 4.1 of the Basin Plan) which effectively prohibit any waste discharges to surface waters The Basin Plan allows exemptions to these prohibitions for discharges of waste earthen materials related to implementation of restoration projects, under specific circumstances.

Table 2. Narrative Water Quality Objectives Related to Eutrophication of ICR

Objective	**Description**
Regionwide Objectives	
Non-Degradation	Requires that findings under Resolution 68-16 be made to allow degradation..
Floating material	Water shall not contain floating materials, including scum in concentrations that cause nuisance or adversely affect beneficial uses.
Unionized Ammonia	Includes limits based on temperature and pH, using tables and equations based on USEPA criteria.
Indian Creek Watershed Objectives	
Algal growth potential	The mean of monthly mean [sic] of algal growth potential shall not be altered.
Biostimulatory Substances	The concentrations of biostimulatory substances shall not be altered.
Dissolved oxygen	The dissolved oxygen concentration shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L, at any time, whichever is more restrictive.
pH	Changes in normal ambient pH levels shall not exceed 0.5 unit.
Species composition	Species composition of the aquatic biota shall not be altered.
Taste and odor	The taste and odor shall not be altered.

Although ICR is Section 303(d)-listed for “eutrophication”, and compliance with all water quality standards is important (and will be achieved), phosphorus was chosen as the focus of the TMDL because the phosphorus objective is the nutrient objective most consistently violated (among the parameters monitored regularly), and because it is a key factor in eutrophication and the eutrophication-related violations of other objectives. Reductions in phosphorus loading to the water column can be expected to lead to reduced productivity of algae and aquatic weeds, with consequent reduced risks of elevated pH, dissolved oxygen depletion and elevated unionized ammonia levels. Reduced risks of high unionized ammonia levels and low dissolved oxygen concentrations will lower the risk of fish kills. Reduced phosphorus concentrations should increase aquatic biodiversity, reduce algal growth potential, and reduce blue-green algal scums (which violate the floating materials objective). ("Algal Growth Potential" is a bioassay method which has not been used at Indian Creek reservoir since the cessation of wastewater disposal.)

The total phosphorus objective for ICR (0.04 mg/L) is at a level higher than the generally accepted threshold for eutrophication of lakes (0.02 mg/L; see the discussion of loading capacity linkage analysis, below). Because of this, the loading capacity (or Total Maximum Daily Load) has been set at a level lower than the current phosphorus objective in order to ensure protection of beneficial uses.

Numerical water quality objectives for ICR were originally expressed as annual means but were revised in 1983-84 (as part of a broader update of water quality standards for the West Fork Carson River and Indian Creek watersheds) to be expressed as "means of monthly means". RWQCB staff used the "mean of monthly means" approach in the early 1980s to set objectives for streams where historical data were not consistently collected throughout the year. (For example, due to Sierra Nevada weather conditions, samples might have been collected more often in summer than in winter.) A mean of monthly means is calculated by averaging all historical data for each month during the period of record and then determining an annual mean from the monthly means. For a relatively undisturbed water body, this method helps to smooth out "spotty" data to give an overall view of historical background water quality.

The "mean of monthly means" approach is *not* appropriate for evaluating the recovery of Indian Creek Reservoir from eutrophication, because nutrient concentrations would be expected to decrease over time with dilution and flushing. (This has been the case for some wastewater constituents in ICR, but for with phosphorus, due to internal loading from the sediment. See Section 3.3, Source Analysis.) Inclusion of pre-1989 data in the mean of monthly means calculations would increase the degree of present-day noncompliance with the phosphorus objective. Because of this problem**,** the numeric total phosphorus target for the TMDL is expressed as an annual mean, rather than a mean of monthly means.

For purposes of the TMDL, the narrative objectives related to protection of beneficial uses are interpreted as requiring less than eutrophic conditions (see the next section of this staff report). When resources permit, the Regional Board should consider revising <u>all</u> numeric objectives for Indian Creek Reservoir to be expressed as annual means, and revising the narrative objectives discussed above to be consistent with protection of beneficial uses.

C. Interpretation of Water Quality Standards: Desired Conditions for Beneficial Use Support

Symptoms of Eutrophication. “Eutrophication" is defined as "the nutrient enrichment of aquatic systems". While it is a natural process, it can be greatly accelerated by human activities which increase nutrient loading. Eutrophic systems typically contain "an undesirable abundance of plant growth", as floating algae (phytoplankton), attached algae (periphyton), and/or macroscopic rooted or free-floating plants, called macrophytes (USEPA, 1999); also see the glossary. The nutrients which are most often involved in eutrophication are nitrogen and phosphorus. In addition to high nutrient supply and high biological productivity, indicators of eutrophication in lakes (Welch and Lindell, 1980) include:

- relatively high density and low biodiversity of phytoplankton; relatively frequent algae blooms;

- dominance of the phytoplankton by green and blue-green algae rather than by the diatoms characteristic of oligotrophic lakes (lakes with low biological productivity). Blue green algae are unpalatable to herbivorous zooplankton and may produce chemicals toxic to fish, livestock, and humans;

- depletion of oxygen in the hypolimnion (deepest part of the lake); and

- rapid growth of fish species tolerant of high temperatures and low oxygen concentrations.

In addition, eutrophication can lead to fish kills due to depletion of dissolved oxygen from respiration by abundant aquatic plants, or due to high levels of unionized ammonia. High unionized ammonia levels are favored by relatively high levels of total ammonia; high pH levels related to algae blooms, and the high temperatures under which such blooms occur.

Many of the biological indicators of eutrophication cited above have been present at ICR at some time during its history. The symptoms of eutrophication are generally most apparent during warm weather conditions. Higher temperatures stimulate biological growth and lead to thermal stratification of lakes. At ICR, these processes are also affected by the fact that the reservoir receives little or no external water input during the summer.

Conditions necessary for beneficial use support. Although eutrophication is a natural process, eutrophic conditions at the levels found in ICR are not compatible with long term support of a recreational trout fishery, which has been the "desired condition" of the reservoir since its construction. Trout require relatively low temperatures and high levels of dissolved oxygen. Eutrophication also affects the organisms used for food by trout and the "food web" that supports these organisms. Ballantyne *et al.* (1999) showed that dominance of algal communities by blue green algae represents a shift from high to low food quality for zooplankton (the "water flea" *Daphnia).* At peak biomass of blue green algae, *Daphnia* growth rates were "quite low". (*Daphnia* or "water fleas" are crustaceans which are important fish food organisms.) Ballantyne *et al.* concluded that the ability of zooplankton to regulate algal biomass in hypereutrophic lakes is seriously limited by the low food quality of blue green algae.

Recreational use of eutrophic lakes and reservoirs is adversely affected by reduced clarity, floating mats of algae, macrophyte interference with boating, swimming, and other recreational activities, slippery beds of macrophytes and attached algae which make wading dangerous, and fouling of fishermen's nets by sloughed material (USEPA, 1999). In addition to contributing to taste and odor problems in water and fish flesh, the blue-green algae favored by eutrophication can contribute to health problems for recreational users**.** Kenworthy *et al*. (1999) stated that toxins released by *Microcystis aeruginosa* in Lake Sammamish, Washington in the fall of 1997 may have been responsible for the death of a pet dog and illnesses of two young children who swam in the lake.

Because of a number of factors (including ICR's artificial nature, shallow conditions which promote high summer temperatures, limitations of water rights on tributary inflow amounts, and the quality of background water supplies) it is not reasonable to expect ICR to reach the oligotrophic conditions prevalent in natural lakes undisturbed by human activities, at higher elevations in Alpine County and elsewhere in the Sierra Nevada. This TMDL focuses on reducing phosphorus loading to levels which will support mesotrophic conditions, which will in turn support aquatic life and recreational uses at acceptable levels. (See the loading capacity linkage analysis discussion in Section 3.4 below.)

D. Summary of Historic and Existing Conditions

During the wastewater disposal period, ICR had ambient nutrient concentrations at levels now considered indicative of "hypereutrophic" conditions (including total P levels greater than 100 ug/L). The reservoir experienced fish kills, and developed other symptoms of eutrophication which became worse as nutrient loading increased throughout the 1970s. STPUD's consultants (Jones & Stokes Associates, 1978) summarized the results of early limnologic studies of ICR as follows (italics added):

> *"Eutrophic indicators abound in ICR. Phytoplankton are numerous yet dominated by few species... . Zooplankton are also abundant... . Aquatic weeds (Myriophyllum, Ceratophyllum and Potamogeton), periphyton, and algae (Cladophora) cover much of the lake bottom. The aquatic weeds have been a particular nuisance to fishermen and boating enthusiasts. Extensive harvesting by STPUD during 1972, 1973 and 1974 failed to significantly reduce the weed beds. Weed decomposition and Oscillatoria blooms have caused odor problems and tainting of fish flesh."*

Eutrophic conditions also provided favorable habitat for midge larvae, and periodic midge swarms interfered with recreation. Dried weeds and snails (up to 500 per square meter at one point) were exposed in the shorezone when the reservoir was low, lowering the quality of the recreational experience.

Adams *et al.* (1979) evaluated the nutrient content of sediment samples taken from ICR in the late 1970s. Total phosphorus concentrations were comparable to those of sediment from eutrophic Lake Mendota, Wisconsin. The authors concluded that

> "*The amounts of phosphorus and nitrogen discharged to ICR are adequate to result in eutrophic conditions.... The biota produced by the fertilization and the physicochemical microbial decay of this material has resulted in a sediment within the reservoir similar to many eutrophic lakes and reservoirs*."

Historic expectations for reservoir recovery. The first attempt to "restore" beneficial uses of ICR was the installation of aerators in 1970, for destratification. (Since ICR is a completely artificial lake, there are no historic "reference" conditions and the term "restoration" is not really appropriate. However, the "lake restoration" literature cited in this staff report is highly relevant to improvement of water quality at ICR.) Aeration of the hypolimnion is a recognized lake restoration method which can (1) raise the oxygen content of the hypolimnion without warming or destratifying the water column, (2) provide better habitat and food supply for cold-water fish in the coldest part of the lake, and (3) reduce the loading of phosphorus from the sediments by establishing aerobic conditions at the surface of the sediment. The effectiveness of aeration in maintaining aerobic sediment conditions depends on the size and design of the aerators, among other things. Summer stratification of ICR was observed in 1976-77, in spite of the use of aerators (Porcella *et al*, 1978). Wood (1978) noted that water mixing from aeration had been "relatively successful" in preventing winter fish kills by preventing complete winter ice cover and associated oxygen depletion, but that it did not affect fish kills from high levels of unionized ammonia.

In the 1970s, STPUD began to prepare a new facilities plan, both to correct problems with its wastewater treatment and export facilities, and to accommodate expanded flows to serve new development in the Lake Tahoe Basin. It considered several alternatives. The one eventually chosen involved changing from tertiary to filtered secondary wastewater treatment, constructing a new reservoir in Alpine County (Harvey Place Reservoir) with a larger capacity for effluent disposal, and obtaining water rights to maintain the level of ICR with fresh water for the support of aquatic life and recreational uses.

During the facilities planning process, STPUD's consultants, Porcella *et al.* (1981), estimated future phosphorus loads to ICR from wastewater under continuation of then-current conditions, and under the increased flows which would occur if the STPUD treatment plant expanded to serve new growth. They concluded that: "The expected phosphorus loadings would be greater than prerestoration loadings to Lake Washington (WA), Lake Sammamish (WA) and Shagawa Lake (MN) which were hypereutrophic prior to expensive restoration". These lakes were then "some of the most hypereutrophic lakes in the world". Porcella *et al.* also stated that increased phosphorus loading to ICR would "lead to significant deterioration of the recreational potential of the reservoir".

Porcella *et al.* (1978) concluded that, if wastewater were replaced with West Fork Carson River water at an inflow rate of 3552 afa (the then-current wastewater input), new steady state conditions for chemical oxygen demand (COD), ammonia, and total nitrogen would be attained within four years The same consultants (Porcella *et al*, 1981) later modeled projected concentrations of pollutants in 1985 and 1990 under different scenarios, using the same 3552 afa West Fork Carson River inflow for the flushing scenario. (This was assumed to be the inflow needed to maintain ICR at a constant level, if downstream ranchers continued to withdraw water for irrigation.) They predicted that the concentration of total phosphorus in ICR would be 0.005 mg/L by 1985, and that it would be at the same level in 1990, compared with an initial (1979) concentration of 0.05 mg/L total P.

Bill Dendy & Associates (1979), consultants to the Alpine County Board of Supervisors, reviewed water quality standards and criteria, existing and then-proposed effluent limitations for ICR, and issues related to protection of beneficial uses. Their report concluded that full support of beneficial uses, including a "growth" rather than a "put and take" trout fishery, body contact recreation, aesthetic enjoyment (in terms of visual attractiveness, odors, insects, and fish taste), protection of public health, and irrigation water supply, could not consistently occur under any of the wastewater treatment alternatives then being considered. The Dendy report recommended that STPUD purchase fresh water to fill the reservoir, and flush it at least once a year with additional fresh water. It predicted that even then there could be problems of clarity, algae, and weed growth, fish flesh tainting, and dissolved oxygen shortages for a few years due to the accumulation of nutrients, notably phosphorus, in the sediment. This period could be minimized if, prior to switching over the Carson River water, the reservoir were "thoroughly cleaned of algae mats, weeds, and accumulated sediment". The Dendy report also recommended that, after switching to Carson River water, ICR should be "flushed at least annually during spring runoff".

A later estimate of minimum flushing flows to maintain a fishery in Indian Creek Reservoir, in the Final Supplemental Environmental Impact Report for the STPUD facilities plan (Jones & Stokes, 1983b) assumed that a 3600 acre- foot flushing flow "would be a reasonable assumption for all but drought years". Jones & Stokes also predicted that mineral sediments from the tributary inflow would gradually seal the organically enriched sediment at the bottom of the reservoir and reduce eutrophication problems. STPUD's 1984 Operations Plan for ICR estimated that, with acquisition of winter flushing flows from Indian Creek, there would be a 50 to 100 percent turnover of water in ICR, and that, over an extended period ICR would be flushed much more than similar Sierra reservoirs. Although the draft Environmental Impact Report (EIR) for STPUD's facilities plan was circulated in 1978, a variety of issues, including Alpine County residents' concern about the impacts of irrigation with secondary effluent on drinking water supplies, delayed the diversion of sewage from ICR until January 1989.

In evaluating current conditions and the potential for improving reservoir quality in the future, it is important to recognize that ICR was not "thoroughly cleaned" after wastewater disposal ceased, as recommended by the Dendy report, and that the water rights acquired by STPUD did not and do not provide for substantial flushing as envisioned in the consultants' reports cited above. Rather, the current fresh water inflow to ICR is used to maintain the water level to counteract losses from evaporation and seepage. Because of the low tributary inflows and the relatively low suspended sediment concentration of tributary water, it is also unlikely that significant burial of organic sediment by inorganic sediment, as predicted by Jones and Stokes, has occurred since 1989.

Water quality trends since 1989. Sampling of ICR between January 1989 and late 1998 was done only at a near-surface station, and the results did not allow conclusions about depth profiles of temperature, dissolved oxygen, or nutrients. Since late 1998, STPUD has done monthly depth profile sampling at several stations in the reservoir, including measurements of dissolved oxygen, temperature, and phosphorus concentrations at different depths. Secchi depth transparency measurements, and more recently, chlorophyll a measurements, have also been done.

Levels of most of the wastewater constituents monitored at ICR have decreased significantly since fresh water inflow began in 1989. This is especially true of constituents such as chloride and total dissolved solids. Recent concentrations of both parameters have been well below the current (wastewater related) water quality objectives for ICR (24 mg/L for chloride and 305 mg/L for TDS), and close to the objectives for the West Fork Carson River (1.0 mg/L for chloride and 55 mg/L for TDS). Total nitrogen concentrations have also decreased. However, total phosphorus concentrations remain high. Frequent violations of the regionwide pH objective (6.5-8.5 units), and occasional violations of the unionized ammonia objective have continued to occur. The pH violations are a result of algae blooms, and high pH contributes to release of unionized ammonia. Monitoring from 1998 to the present shows that summer stratification and dissolved oxygen depletion in the hypolimnion occur. A fish kill occurred in June 1999; its causes were not determined.

Ratios of total N to total P in ICR data for recent years indicate that phosphorus is currently the "limiting nutrient" (i.e., the N:P ratio is greater than 7.2:1 , the ratio cited in the USEPA's 1999 protocol for development of nutrient TMDLs). The reservoir is currently dominated by nitrogen fixing blue-green algae, which lessens the importance of ambient nitrogen in regulating productivity.

Nitrogen fixing blue-green algae were not observed in ICR during the early 1970s, probably because the relatively high concentration of nitrogen did not give them a competitive advantage over other types of algae (Porcella *et al*., 1978). The decrease in ambient nitrogen concentrations since wastewater disposal ceased, together with continued high phosphorus levels, has created an advantage for nitrogen fixers. STPUD’s monitoring data since 1989 show the presence, sometimes in large numbers, of the nitrogen-fixing blue green algae *Anabaena, Aphanizomenon, and Gleotrichia,* and of the non-nitrogen fixing “nuisance” alga *Microcystis.* These genera of blue-green algae are indicators of eutrophication. Some strains of *Anabaena* and *Microcystis* are known to be toxic to vertebrate and invertebrate consumers (Sandgren, 1988).

The impacts of historic and existing discharges from ICR on the water quality and beneficial uses of downstream waters of the outlet channel, Indian Creek, and the East Fork Carson River in Nevada have not been specifically documented. Nutrients are monitored at downstream stations; however, station locations do not allow the impacts of the reservoir to be separated from those of pasture runoff and irrigation return flows. Because releases from the reservoir occur mainly during the winter when reservoir oxygen concentrations are high, dissolved oxygen is probably not currently a problem downstream.

Section 3.2. Numeric Targets

Section 303(d)(1)C of the Clean Water Act states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards". The numeric targets developed for the Indian Creek Reservoir TMDL are intended to interpret the narrative and numeric water quality objectives, which in turn provide for support of designated beneficial uses. Under existing laws, numeric targets for TMDLs are goals, not enforceable water quality standards. The Regional Board can take enforcement action, consistent with the TMDL, for actual or threatened discharges to surface waters which violate applicable water quality standards (including beneficial uses and narrative and numerical water quality objectives).

This TMDL focuses on total phosphorus, since the literature review indicates that reduced phosphorus loading would: 1) reduce algal productivity; 2) reduce dissolved oxygen depletion during summer stratification, and thus reduce the associated risk of fish kills; 3) increase transparency; and 4) protect and enhance aquatic life and recreational uses. Targets and indicators for parameters other than total P are also proposed in order to track recovery from eutrophication. The targets and indicators are summarized in Table 3. See Section 5.4 below for a discussion of the proposed TMDL monitoring program.

A. Total Phosphorus

1. Numeric Target

The proposed numeric target for total phosphorus is 0.02 mg/L, as the annual mean concentration in the water column. This is roughly equivalent to the numerical water quality objective for the West Fork Carson River (which is a mean of annual means) in the reach which provides tributary flow to the reservoir) and is much lower than the current phosphorus objective for ICR (0.04 mg/L). The scientific peer reviewer for a preliminary draft of the ICR TMDL commented on the inadequacy of the current water quality objective to protect beneficial uses, and recommended that the numeric target for the TMDL be set at a lower level. Regional Board staff's literature review indicates that the proposed target can feasibly be attained if best management practices are implemented to control external sources, and if phosphorus release from the sediment is inactivated, or phosphorus-rich sediment is removed.

Table 3. Numeric targets and Indicators for Indian Creek Reservoir TMDL

Indicator	Target Value	Reference
Indian Creek Reservoir*		
Total P concentration	No greater than 0.02 mg/L, annual mean	USEPA, 1988, 1999.
Dissolved Oxygen	Shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L at any time, whichever is more restrictive.	(Water quality objective) Basin Plan, Chapter 3, pages 3-10 to 3-11.
Secchi depth	Summer mean no less than 2 meters	USEPA, 1988. 1999
Chlorophyll a	Summer mean no greater than 10 ug/L	USEPA, 1988,1999
Carlson Trophic Status Index	Composite index no greater than 45 units	USEPA 1988, 1999
Tributary Inflow Ditch*		
Total P Concentration	No greater than 0.0225, ten year rolling average	Concentration which corresponds to load allocation.

* These indicators will be measured for at least one depth profile sampling station.
** This indicator will be measured at the established monitoring station closest to the reservoir.

The total phosphorus target is based on the literature rather than on reference lake conditions because there are no nearby, relatively undisturbed natural lakes or reservoirs with similar geologic and climatic conditions. ICR is located near the transition between the Sierra Nevada and Great Basin ecoregions. Wilderness lakes at higher elevations for which data are available tend to have low phosphorus concentrations; mean total P in

Gilmore Lake in Desolation Wilderness was 0.012 mg/L in 1975-76 (USEPA STORET database). Other eastern Sierra reservoirs at elevations similar to that of ICR (e.g., Topaz Lake, Bridgeport Reservoir, and the reservoirs in the Los Angeles Department of Water and Power's Owens Valley system) are significantly affected by human activities in their watersheds, and some of them are also Section 303(d)-listed for eutrophication.

Given the background quality of the inflow water, and the efficiency of potential control measures, the proposed phosphorus target is probably the lowest phosphorus concentration which can feasibly be attained. See the Loading Capacity Linkage Analysis section below for additional discussion of this target.

2. Comparison of numeric target and existing conditions

Total phosphorus concentrations have decreased by about an order of magnitude since wastewater disposal to ICR ceased, although existing concentrations are still in the eutrophic range. Data from 1982 (32 samples) summarized in the Regional Board staff report for the 1983-84 Basin Plan update had annual mean of monthly means of 0.55 mg/L, and a maximum value of 0.77 mg/L.

Mean annual total phosphorus concentrations in ICR, (based through 1997 only on monthly near-surface samples), have varied but have not shown any definite trends since 1989 (see Table 4). Since late 1998, STPUD has taken monthly total phosphorus samples at three different depths at each of several sampling stations within the lake. (Sampling is not done during winter ice cover conditions; 10 samples were collected during 1999.) Measured total phosphorus values have been generally in the eutrophic to hypereutrophic range; some very high concentrations were recorded in the hypolimnion (0.22 mg/L in October 1999, 0.11 mg/L in February 2000; 0.640 at 17.5 feet and 0.158 at 36 feet in August 2000). In 1999, the year used for TMDL loading calculations, surface concentrations of total P for Station ICR-1 ranged from 0.04 in June to 0.09 in November and December. The calculated annual mean for 1999 was 0.08 mg/L total P.

B. Dissolved Oxygen

Dissolved oxygen was selected as an indicator for the TMDL because dissolved oxygen depletion is a common symptom of eutrophication, because salmonids (fish in the trout family) require relatively high levels of dissolved oxygen, and because anoxic conditions promote release of phosphorus from lake sediments.

1. Numeric target

The numeric target is equivalent to the narrative water quality objective (Table 2, above). It is an instantaneous objective to be achieved at all times. The Basin Plan is silent as to whether the objective applies to the entire water column, but given the lack of qualification, it is presumed to do so. (The regionwide dissolved oxygen objectives in

Table 3-6 on Basin Plan page 3-23 are less stringent than the ICR objective for waters with similar aquatic life use designations.)

2. Comparison of numeric target and existing conditions.

Monthly depth profile monitoring by the STPUD since 1998 shows that ICR stratifies during the summer. Thermal stratification begins approximately in April and ends by mid to late October. Dissolved oxygen reaches levels below 1 mg/L near the sediment by mid-June and levels in the hypolimnion remain low until fall overturn. Oxygen levels in the epilimnion can also reach levels which violate the objective (as low as 5.19 mg/L near the surface in September 1999). Winter oxygen concentrations are higher than the objective (greater than 11.00 mg/L in February 2000).

Dissolved oxygen concentrations below 6 mg/L are well below the optimum levels for growth, food conversion, and food intake by trout. Thresholds below which “serious effects” on these processes may occur are 6 mg/L for growth, 5 mg/L for food intake, and 4 mg/L for food conversion (Colt et al, 1980). The TMDL target/current objective of 7 mg/L for ICR is above these thresholds.

C. Secchi Depth

Secchi depth (see the glossary) is a measure of water transparency, which in turn reflects the amount of planktonic algae and other floating organic and inorganic particles in the water column. The USEPA has developed a separate set of cross tabulations of total phosphorus, chlorophyll a and transparency values based on data collected from 894 U.S. lakes and reservoirs in the National Eutrophication Survey (summarized in USEPA, 1988 and Appendix 3). Based on these figures, a Secchi depth of 1-2 meters corresponds to eutrophic conditions, and a Secchi depth of less than 1 meter to "hypereutrophic" conditions.

1. Numeric target

The target for the TMDL is a summer mean Secchi depth no less than 2 meters. The literature indicates that this is the threshold between mesotrophic and eutrophic conditions.

2. Comparison of numeric target and existing conditions

The waters of ICR were very clear during the early 1970s (maximum Secchi depth 28.5 feet in 1973: Lake Tahoe Area Council, 1975). Since diversion of wastewater, ICR has become turbid, with high concentrations of blue-green algae, although macrophytes are still present. Current limnological thinking identifies two "alternative stable states" for shallow eutrophic lakes, one turbid and dominated by phytoplankton and the other clear and dominated by macrophytes. Switching between these states can occur. The turbid state is "driven by nutrient recycling from the sediments" (Carpenter and Cottingham, 1997). Reported Secchi in ICR depths since STPUD began depth profile sampling in 1998 range from 2.2 feet in May 1999 to 7.0 feet in September 1999.

D. Chlorophyll a.

Chlorophyll a is found in all algae and higher plants. The concentration of chlorophyll a is an indicator of plant biomass. According to the literature, chlorophyll a concentrations between 10 and 100 ug/L are indicators of eutrophic conditions (Welch and Lindell, 1980). The greatest improvement in Secchi depth occurs when chlorophyll a is reduced below 20 ug/L. Welch and Lindell (1980) state that it is important for management purposes to realize that chlorophyll a must be lowered to levels below 20 ug/L before much noticeable improvement in water clarity can be seen. Using the National Eutrophication Survey data summarized in Appendix 3, a chlorophyll a concentration of 10-25 ppb corresponds to eutrophic conditions, and a concentration of 4-10 ug/L to mesotrophic conditions.

1. Numeric target

The numeric target is a summer mean chlorophyll a concentration in the epilimnion no greater than 10 mg/L.

2. Comparison of numeric target and existing conditions

There have been relatively few historic measurements of chlorophyll in ICR. Wood (1978) reported chlorophyll a concentrations up to 115 mg/m^3 (equivalent to ug/L) from a 1976-77 study, when the reservoir was receiving wastewater. STPUD began collection of monthly chlorophyll a samples in 2000. In August 2000, the concentration was 41.0 mg/m^3 at 0.5 feet, 8.5 ug/m^3 at 17.5 ft, and 10.0 mg/m^3 at 36 feet. The surface value is within the "eutrophic" range, based on the literature review.

E. Carlson Trophic State Index

The Carlson Trophic State Index (TSI), which was developed empirically from measurements in a number of north temperate lakes, allows evaluation of lake trophic status (oligotrophic, mesotrophic, or eutrophic) based on equations related to chlorophyll a, total P, and Secchi depth. The USEPA's protocol document for developing nutrient TMDLs (1999) identifies the TSI as "a means of identifying site-specific target values for nutrient TMDLs." The equations, and the TSI are summarized in Appendix 2. The index, which is without units, allows comparison of measurements between lakes. The TSI is widely used in Section 305(b) lake assessment by state water quality agencies and because of its simplicity, in volunteer monitoring. There has been a tendency for users of the index to compute a single composite index value by taking the mean of the three index values for chlorophyll a, Secchi depth, and total phosphorus. Dr. R. E. Carlson, the originator of the index, disagrees with this approach and provides direction for the evaluation of trophic state using the three *separate* indices (Carlson and Simpson, 1996).

The TSI involves a unitless scale of 0 to 100, or 0 to 120, with the range from 40 to 50 representing the transition between mesotrophic and eutrophic conditions. Some references use 50 as the threshold score; however, the USEPA's 1999 TMDL nutrient protocol document (see Appendix 3) interprets a TSI greater than 45 as eutrophic. In addition to the logarithmic equations used to compute the indices bar graphs have been determined to relate TSI scores to sampling data and trophic status; see Appendix 3.

There is apparently no "standard" number or frequency of samples required to compute the TSI; it has been computed on the basis of single sampling runs. Some studies use summer mean values of the three parameters; this approach will be used for the ICR TMDL.

1. Numeric target

The proposed target involves TSI values less than 45, representing mesotrophic conditions, for each of the three components of the index. Calculations should be done using mean summer total P (surface), chlorophyll a (surface) and Secchi depth values (means for June through September). The use of 45 rather than 50 as the threshold value follows the USEPA protocol, and adds to the TMDL margin of safety. The literature (Carlson and Simpson, 1996) indicates that under mesotrophic conditions (between TSI values of 40 and 50) there is an increasing probability of anoxia in the hypolimnion during the summer.

The indicators and targets above for total phosphorus, chlorophyll a, and Secchi depth will be evaluated separately from the TSI components (e.g., in relation to the National Eutrophication Survey data summarized in Appendix 3).

2. Comparison of numeric target and existing conditions

Using the bar graph in Appendix 3, the summer surface P (about 0.055 mg/L in 1999) and chlorophyll a concentrations reported in recent years correspond to TSI values between 60 and 70 (hypereutrophic) and the Secchi depth values are between 50 and 60 (eutrophic). The TSI literature indicates that lakes dominated by large colonial algae such as *Aphanizomenon* (which is present at ICR) may have more transparent conditions than would be expected from the chlorophyll measurements (Carlson and Simpson, 1996).

Section 3.3. Source Analysis

All current sources of phosphorus loading to ICR are considered nonpoint sources. (The former wastewater discharge was a point source discharge under an NPDES permit. However, current loading of residual wastewater phosphorus from the sediment occurs in a diffuse manner from an area of about 110 inundated acres and through surface runoff from about 50 acres which was formerly inundated at maximum reservoir levels.) The source analysis discussion below summarizes the methods used to estimate the existing phosphorus loads to ICR from external and internal nonpoint sources. External sources (and the load allocations in Section 3.5) are grouped in general categories. More specific sources in the watershed which could contribute to phosphorus loading in both the "runoff" and “tributary stream” categories include livestock grazing in the upper watershed, unpaved roads and other watershed disturbance, and erosion from streambanks, irrigation ditches, and unvegetated portions of the shorezone. Phosphorus loading data from these specific categories are not available. Variation in the use of water rights makes it infeasible to divide source loading estimates and load allocations among different areas of the watershed tributary to the inflow ditch, so a single "tributary inflow" category is used.

A. Data and methods used

Development of the TMDL began with the review of monitoring data from RWQCB and STPUD files. The Regional Board does not currently require STPUD to monitor ICR, but the District does so and submits data to the RWQCB as part of the required monthly and annual monitoring reports on its wastewater treatment and disposal activities in the Lake Tahoe Basin and Alpine County. Almost all data were obtained in electronic form from STPUD’s laboratory director or from reports prepared by STPUD’s consultants. Computer disk copies of the laboratory information will be made part of the administrative record. Hal Bird of STPUD staff (personal communication, 1998-2000) provided information about current water rights and reservoir operating practices. Staff also reviewed other information on ICR from the RWQCB and STPUD files and libraries and from Alpine County files, and readily available literature on eutrophication and lake restoration. Staff of the U.S. Bureau of Land Management, the California Department of Fish and Game, and the Federal Watermaster’s office were consulted.

Limnological studies of the reservoir were conducted during the 1970s, and the results were evaluated by STPUD’s consultants (e.g., Lake Tahoe Area Council, 1975; Porcella *et al.* 1978, 1981) and the California Department of Fish and Game (Wood, 1978). No detailed biological sampling, other than STPUD's monthly algae counts, has been done since that time. The California Department of Fish and Game has continued to observe the reservoir in terms of overwinter survival of planted trout and abundance of nongame fish species. There are no recent quantitative data on macrophytes, zooplankton, or benthic invertebrates. The proposed TMDL is based on water chemistry and flow data, and involves mass balance calculations for total phosphorus loading.

In response to comments by the scientific peer reviewer on the first preliminary draft, an additional literature review was done to provide the basis for estimating internal phosphorus loading from the sediment. Information from STPUD's depth profile sampling of dissolved oxygen (beginning in 1998) was used to estimate the duration of anoxic conditions in order to estimate internal phosphorus loading in the hypolimnion during the summer. The literature review was also used in selection of a new numeric target for the TMDL and in development of a revised implementation program.

Modeling of historical inputs and outputs of water and phosphorus to the water column of Indian Creek Reservoir, and of projected future load reductions, was done with Excel spreadsheet software and a calculator. Data from diverse sources were converted to common units for use in calculations. Tables 5 and 6 contain tributary inflow data for the West Fork Carson River and Indian Creek. Table 9 summarizes the results of the source analysis. Loads are rounded to the nearest pound.

Table 7. Summary of Parameters Used in TMDL Calculations

Parameter	**Value**
Indian Creek Reservoir	
Volume of reservoir (acre feet)	1515
Surface Area (acres)	110
Anoxic sediment area in summer (acres)	23
Remainder of sediment area (acres)	87
Volume of hypolimnion (acre feet)	475
Mean Depth (volume/surface area), feet	13.7
Osgood Index (mean depth/ square root of area)	0.006
Tributary watershed contributing direct runoff	
Total area including reservoir (acres)	1700
Area contributing runoff (acres)	1590
Runoff volume (acre feet/annum or afa)	762

B. External Loading

1. Precipitation on Reservoir Surface

Calculations of phosphorus loading in precipitation used the average annual rainfall for the community of Woodfords, near ICR (equivalent to 1.66 feet per year) and the average concentration of total P measured in precipitation in the Lake Tahoe watershed (6.5 ug/L, average from unpublished data supplied by John Reuter, University of California, Davis Tahoe Research Group). Using a reservoir surface area of 110 acres, the estimated load of total phosphorus from precipitation is 3 pounds per year.

2. Surface runoff from the tributary watershed.

Culp/Wesner/Culp (1980) calculated surface runoff from the Indian Creek Reservoir watershed, including the area of the reservoir itself, using precipitation totals at Woodfords for each month of the year, multiplied by a runoff factor for each month, multiplied by the 1700 acre reservoir area. Monthly runoff figures in acre feet were summarized to give an runoff total of 815 acre feet per annum (afa). For the TMDL, runoff totals were recalculated using a watershed area of 1590 acres (1700- 110 acres). The total runoff to the reservoir is now 762 afa. The annual load of total phosphorus in this amount of runoff was calculated using data for phosphate concentration in runoff from relatively undisturbed lands in the Lake Tahoe Basin and converting phosphate loading to total P loading using the molecular weight of phosphorus. The calculated load of total P to the reservoir from surface runoff is 68 pounds per year.

3. Loading from tributary inflow

ICR has no natural tributary stream inputs. Water diverted from the West Fork Carson River and Indian Creek is routed to the reservoir via unlined irrigation ditches (part of Snowshoe Thompson Ditch #1 is vegetated). Surface water diversions in the California portion of the Carson River watershed are regulated by a federal watermaster under the "Alpine Decree" (United States of America v. Alpine Land and Reservoir Company, U.S.D.C., D. Nev., Civ. No.D-183 [1980]). The constraints of the Alpine Decree are important considerations in planning for future water quality improvements in Indian Creek Reservoir because they make it unlikely that additional surface water rights to provide significant dilution or flushing for ICR will be available in the future, and limit the manner in which existing water rights can be used. STPUD's agreement with Alpine County calls for maintaining a given minimum pool reservoir level and not for a specific amount of annual flushing. The current maximum potential tributary inflow amounts reflect water rights which were available for purchase.

STPUD has acquired 555 afa of water rights (250 afa from the West Fork Carson River and 305 afa from Indian Creek), which are used as "makeup water" to offset seepage and evaporation from ICR and to maintain the reservoir at or above normal and dry year "minimum pool" levels agreed upon between STPUD and Alpine County. No water is released from the reservoir in connection with this inflow, and so it should not be viewed as "flushing flow". The reservoir receives some flushing flows during the non-irrigation season (October 1 through March 31). Water is diverted from Indian Creek when there is sufficient flow and is measured before it enters the reservoir. This water is for non-consumptive use, meaning that the amount entering the reservoir must be the same as the amount exiting. Some additional flushing may occur during years with high runoff, but this is not taken into account in the TMDL calculations below. Inflow and outflow data for ICR are summarized in Table 5. The calculations use inflow data for 1999 (a total of 593 acre feet).

Water quality data for the tributary inflow to ICR are summarized in Table 6. Monthly water quality samples collected by STPUD between 1980 and 1999 for the West Fork Carson River at the Woodfords diversion point show that the river attains its numerical water quality objective for phosphorus (0.02 mg/L, mean of monthly means). Monthly water quality data for Indian Creek were collected less frequently between 1980 and about 1994; more frequent measurements were taken between 1995 and 1999. Using monthly medians of the long term data, inflow from Indian Creek has a total P concentration of about 0.029 mg/L.

Staff used phosphorus concentration data for the "Indian Creek" station in Table 6 and flow data for the ICR inflow water collected between January 1997 and December 1999

(18 sampling periods) to calculate "existing" tributary phosphorus loads. (Long term median concentration values were substituted for four sample values which were either missing or anomalously high.) Calculated P loads were 75.7 pounds for 1997, 63.1 pounds for 1998, and 42.8 pounds for 1999. The reservoir received 2505.7 acre-feet of water during this three year period, including 676 acre feet as runoff from the watershed in January 1997. The 1999 phosphorus load was used as the "existing" value for the TMDL calculations, since the 1997 load was affected by the flood event and the diversion ditch system was damaged by the flood and subsequently repaired. The estimated load of total phosphorus to ICR from the tributary inflow is 43 pounds per year.

4. Possible minor sources of external loading.

Other possible sources of phosphorus loading to the water column of ICR include wastewater from boats, bird droppings, windblown dust, decomposition of planted trout, and seepage from ground water. Dry deposition has not been quantified, but dust from some of the largest unvegetated areas (the unpaved road and boat ramp) is probably carried away from rather than toward ICR by prevailing winds.

Seepage of ground water into the reservoir is another possible source of phosphorus. The extent of the ground water aquifer surrounding ICR, and the potential amount of groundwater inflow to the reservoir are unknown; the watershed is fairly steep and there is probably a relatively small ground water basin. The quality of groundwater may be influenced by septic system discharges from recreational facilities; however, phosphorus from septic systems is much less mobile than nitrogen. Sharpley (1999) in a discussion of agricultural soils stated that the concentration and loss of P in subsurface flow is small because of sorption of P by P deficient soils; greater P losses through seepage can occur in acidic organic or peaty soils than in mineral soils. The natural soils surrounding ICR support mostly upland rather than riparian/wetland vegetation, and appear to be mineral soils rather than peaty soils. As noted below, seepage *from* the reservoir is considered minimal. Loading of P by seepage *to* the reservoir is considered *de minimis* for purposes of the TMDL and is not included in the calculations.

Phosphorus loads associated with the minor sources summarized above cannot be quantified at this time and are assumed to be "de minimis" for purposes of the TMDL calculations.

C. Internal Loading

During the 1970s and early 1980s, STPUD's consultants believed that most phosphorus entering ICR, including inputs from wastewater, would be permanently immobilized in the sediments, and that phosphorus in the water column could be significantly reduced by flushing the reservoir with large volumes of fresh water (see Section 3.1 above). Since that time, a large body of scientific literature has accumulated on attempts to improve the water quality of eutrophic lakes and reservoirs. It has become apparent that "internal loading" of phosphorus from the sediment can greatly increase the time required for recovery over that which would be expected from calculations based on reduced external loads, and outflow data (Welch and Cooke, 1999). The high concentration of phosphorus in the water column of ICR during the summer eleven years after the last wastewater disposal supports the conclusion that internal loading is an important component of the reservoir's phosphorus budget.

1. Release of phosphorus from the sediment

Factors affecting phosphorus release from lake and reservoir sediment include: temperature, oxygen concentrations in surface sediments and adjacent water, ionic concentrations (especially for iron and its compounds), redox potential, light intensity, bioturbation (digging or other movement of sediment by aquatic animals), and lake/reservoir morphology. In shallow lakes, factors regulating adsorption/desorption of P can change radically in days to hours. The ratio of sediment surface to water volume is higher in shallow lakes than in deep lakes, and wind mixing can resuspend sediment more easily (Wisniewski, 1999; De Gasperi *et al*., 1993). Based on "before and after" measurements for a large (270 km2) shallow lake in Estonia, Noges and Kisand (1999), estimated that additional internal P load due to wind mixing from a single stormy day amounted to 193 mg/m^2 of soluble reactive phosphorus and 377 mg/m^2 of total phosphorus. These release rates are very large compared with other daily release rates from the literature; see Table 8.

The release of phosphorus from lake sediment occurs through both abiotic and biotic processes. Recent literature indicates that it is largely a biological process (Mitchell and Baldwin, 1998). The availability of phosphorus depends to a large extent on whether the sediment/water interface is aerobic or anaerobic. More phosphorus is released under anaerobic conditions than under aerobic conditions, and anaerobic release is higher under high pH levels. The availability of phosphorus can also be affected by a variety of environmental factors, including wetting and drying of shorezone sediments as reservoir levels fluctuate (Mitchell and Baldwin, 1998). Den Heyer and Kalff (1998) found that organic matter mineralization in littoral [shorezone] sediments was more variable, and, on average, three times that in the deepest sediments due to factors such as higher temperatures and a richer substrate for decomposition. Cooke *et al*. (1993) note that sediments underlying the epilimnion are likely to release phosphorus because of factors including warm temperatures, high pH from photosynthetic activities, and day/night cycles between oxic and anoxic conditions. Bacterially mediated changes in the redox potential of relatively warm sediments of shallow lakes may lead to significant phosphorus release even if the water column is aerated (De Gasperi *et al.*,1993).

Table 8 summarizes internal phosphorus loading rates from the literature, including data from anoxic and oxic lakes, and laboratory studies of sediment cores. Welch and Cooke (1995) state that the recorded high rates of 30-60 mg/m2 /day are usually from hypereutrophic lakes whether stratified or unstratified. More typical release rates are 2-5 mg/m2 /day.

In strongly stratified lakes which do not mix during the summer, phosphorus does not reach the epilimnion until thermal stratification ends in the fall and causes fall overturn (Welch and Cooke, 1995). However, there is evidence that ICR is one of a class of shallow lakes in which phosphorus from the hypolimnion <u>is</u> available to algae during the summer. The "Osgood Index", calculated as the mean depth of a lake divided by its the square root of its surface area, has been used to predict the likelihood that a lake will mix due to wind action and bring phosphorus to surface waters. In the original study of 96 lakes in Minnesota, lakes with an index value of less than 6 to 7 were lakes in which summer surface water total P exceeded the concentration predicted from external loading (Cooke *et al.*, 1993). The mixing model has been confirmed by comparing Osgood Index values with the results of field studies of vertical P transport. De Gasperi *et al*. (1993) theorized that anaerobic P release during periods of slight stratification followed by wind mixing may be a major source in shallow lakes.

The Osgood Index value for ICR, calculated from the area and volume used in the TMDL calculations, is 0.006. This is lower than any of the index values cited by Cooke *et al*. (1993) and suggests that vertical transport of P during the summer is highly probable. STPUD's monitoring data, which show high concentrations of P, and sometimes low dissolved oxygen concentrations near the surface in summer, are also evidence that summer mixing occurs.

No recent data on sediment phosphorus concentration in ICR, or laboratory studies of phosphorus release rates from ICR sediment, are available. For purposes of this TMDL, the assumption is made that, if current environmental conditions continue, *all* of the phosphorus in the sediment will eventually be available for biological uptake. Earlier samples (Adams *et al.*, 1979; STPUD, 1991) showed that the organic sediment in ICR was about 6 inches (15 cm) deep. Wetzel (1975) cites a study which showed that in undisturbed anoxic sediments, over a 2-3 month period, phosphorus moved upward readily from at least a depth of 10 cm to the overlying water, regardless of whether the sediments were calcareous or acidic and peaty.

To obtain an idea of the total amount of sediment phosphorus to be controlled, Regional Board staff estimated the net cumulative historic loading of phosphorus to ICR during the wastewater disposal period (1969- January 1989) using data on wastewater quality and flows, and estimates of phosphorus outflow during that time, and inflow/outflow data since 1989. The estimated total cumulative load is 52,965 pounds, a very large amount compared to the annual phosphorus loads in the external inflow and outflow which are summarized in Table 9. If internal loading from the sediment is not controlled, Indian Creek Reservoir clearly has the potential to remain eutrophic for many years to come.

The total internal load of phosphorus in ICR can be estimated by adding the load in the water column and the load in the outflow, and subtracting the external load. Using the mean water column concentration of 0.08 mg/L total P for 1999 and a reservoir volume of 1515 acre feet, the water column load was 330 lb/yr. The 1999 phosphorus load in the outflow was 137 lb/yr. Adding this to the water column load and subtracting the external load of 114 lb/yr gives a net internal load of 354 lb/yr. Part of this total is assumed to come from anoxic sediment in the hypolimnion during summer stratification, part from oxic sediment in the epilimnion during the summer, and part from oxic sediment in the whole reservoir during the rest of the year. (This is a simplifying assumption in that phosphorus from anoxic sediment may be mixed into the epilimnion by wind action and overlie "oxic" sediment during the summer, and bluegreen algae may carry phosphorus from the sediment to the surface.)

Figure 3 is a depth contour map of ICR, showing that much of it is relatively shallow. Figure 4 is a graph prepared by STPUD's consultants (Culp/Wesner/Culp, 1980) showing the relation between gage height and reservoir area and volume. Using these figures and the depth of the thermocline based on STPUD's monitoring data, staff estimated the area of anoxic sediment during summer stratification as 23 acres.

Internal loading of phosphorus from the sediment of ICR under anoxic conditions was calculated from the following equation, which is said to give values comparable to those obtained from laboratory studies of sediment cores (Welch and Cooke, 1999).

$$(TP_2-TP_1)*V/(t_2-t_1)/A$$

where (TP_2-TP_1) is the increase in hypolimnetic total phosphorus concentration during the period of stratification, V is the hypolimnetic volume, (t_2-t_1) is the stratification time and A is the hypolimnetic sediment area. This is technically a net sediment release rate (gross release minus sedimentation of dissolved P). Using 1999 phosphorus concentration data for ICR (TP_2-TP_1 = 0.16 mg/L) , the release rate was calculated assuming a 23 acre anoxic zone, a water volume of 475 acre-feet overlying this zone, and a stratification period 120 days long (from early June to late September). The resulting release rate is 8.24 mg/m^2/day. This is within the range of sediment phosphorus release rates for anoxic lakes in Table 8. Over the 120 day period, the total estimated load from *anoxic* sediment in ICR is 92.8 kg, or 204 pounds.

Subtraction of this load from the total estimated internal load of 354 pounds per year gives an estimated load of 150 pounds per year from *oxic* sediment. Calculations using various potential phosphorus release rates show that this amount is best accounted for by

Table 8. Phosphorus release rates from lake and reservoir sediment

Lake Name and Location	**P release rate mg/m^2/day**	**oxic or anoxic**	**Method**	**Reference**
Green Lake WA	2.7	anoxic	lab incubation	De Gasperi *et al.* 1993
Bort-les-Orgues, France	18 (as PO4)	anoxic	lab incubation	Ruban and Demare, 1998
Eau Galle Reservoir, WI	5	oxic	lab incubation	Barko *et al.*, 1990.
Lake Delavan, WI	29	anoxic	model	Field, 1985
Furosoe	-4.5	oxic	lab incubation	Nurnberg, 1984
Estrom	-1.4	oxic	lab incubation	Nurnberg, 1984
St. Gribsoe	0.2	oxic	lab incubation	Nurnberg, 1984
Grane Langsoe	0.6	oxic	lab incubation	Nurnberg, 1984
Glanningen	2	oxic	lab incubation	Nurnberg, 1984
Ramsjoen	0.3	oxic	lab incubation	Nurnberg, 1984
Ryssbysioen	0.7	oxic	lab incubation	Nurnberg, 1984
Charles East	-16	oxic	lab incubation	Nurnberg, 1984
Trummen	0.3	oxic	lab incubation	Nurnberg, 1984
Arungen	1.0	oxic	lab incubation	Nurnberg, 1984
Ontario	0.2	oxic	lab incubation	Nurnberg, 1984
Mendota	10.8	anoxic		Nurnberg, 1984
Shagawa	12.1	anoxic		Nurnberg, 1984
White Lake	19	anoxic		Nurnberg, 1984
Bergundasjoen	24.5	anoxic		Nurnberg, 1984
Rotsee	28	anoxic		Nurnberg, 1984
Muggelsee, Germany	1.6-27.9	oxic	lab incubation	Kozerski and Kleeberg, 1998
Muggelsee, Germany	8.3-125.0	anoxic	lab incubation	Kozerski and Kleeberg, 1998
Red Chalk, East	0.05	anoxic	lab incubation	Nurnberg, 1988
PT-10	0.04	anoxic	lab incubation	Nurnberg, 1988
Chub	1.43	anoxic	lab incubation	Nurnberg, 1988
Gravenhurst	5.27	anoxic	lab incubation	Nurnberg, 1988
St. George	2.22	anoxic	lab incubation	Nurnberg, 1988
Wonon, deep	7.30	anoxic	lab incubation	Nurnberg, 1988
Wonon, shallow	2.10	anoxic	lab incubation	Nurnberg, 1988
Waramaug	9.22	anoxic	lab incubation	Nurnberg, 1988
Arreso, Denmark	40	oxic?		Welch and Cooke 1995
Vallentuna, SK	10	oxic?		Welch and Cooke 1995
Sobygaard, Denmark	53	anoxic		Welch and Cooke 1995
Glum So, Denmark	20	anoxic		Welch and Cooke 1995
Klamath, OR	6	oxic?		Welch and Cooke 1995
Long, WA	2.6	anoxic		Welch and Cooke 1995
Neagh, Great Britain	4.4	anoxic		Welch and Cooke 1995
Hylke So, Denmark	20	anoxic		Welch and Cooke 1995
Alderfen Broad, Great Britain	3.5	oxic?		Welch and Cooke 1995
Long, WA	0.27*	unstratified		Rydin *et al*., 2000
Cambell, WA	0.27*	unstratified		Rydin *et al*., 2000
Erie, WA	1.37*	unstratified		Rydin *et al*., 2000
Ballinger, WA	0.55*	stratified		Rydin *et al*., 2000
Phantom	1.64*	stratified		Rydin *et al*., 2000

* Rydin et al. reported internal P loading as grams/m^2/year; the values in this table were converted using a 365 day year.

an oxic release rate of 0.45 mg/m^2 /day, which is within the range of values reported in the literature (Table 8).

Estimation of the relative loads from oxic vs. anoxic sediment is important because it may influence the choice of implementation methods. For example, adding oxygen to the hypolimnion would apparently treat only about 60 percent of the internal phosphorus loading.

2. Phosphorus storage in biomass and recycling in the water column.

At any one time, there is probably a considerable amount of phosphorus tied up in living and dead biomass in the water column of ICR, including phytoplankton, zooplankton, attached algae, macrophytes, fish, benthic invertebrates, and detritus. Unfiltered “total phosphorus” samples can include fine particles, algal cells, etc. Some phosphorus enters the water column through excretion from living organisms and chemical or biological decomposition of dead organisms, and is in turn removed by biological uptake. Recent research at Green Lake in Seattle, Washington (Perakis *et al.*, 1996) shows that several types of bluegreen algae which are common in ICR can transport significant amounts of phosphorus from the sediment to the surface when algal “resting stages” become active and migrate. The algal-transported P amounts reported for Green Lake (ranging from 1.35 to 30.6 mg P/m^2) were comparable to measured and estimated internal loading from the sediment to the overlying water column as reported elsewhere in the literature. The blue-green alga *Gloeotricha* transported an estimated 22.7 kg (50 pounds) of phosphorus from the sediment of Green Lake to overlying waters in 1992; other species of algae transported additional phosphorus.

Aside from limited data on phytoplankton cell and colony numbers, no recent information is available on biological populations or biomass in ICR. Internal loading from phosphorus recycling within the water column has not been included as a separate factor in the TMDL calculations. Storage and recycling in living biomass in the water column are assumed to be accounted for in the estimates of total phosphorus loading. The generally large differences between the total P and orthophosphate concentrations monitored in ICR indicate that most of the total P is in organic form.

D. Phosphorus Outputs

1. Outputs from Reservoir Releases.

The STPUD monitoring station downstream of the reservoir is some distance from the outlet, and its water quality may be affected by nutrients from nonpoint source agricultural runoff. Rather than using data from this station, the TMDL calculations assume that the phosphorus concentration in the outflow is same as that in the reservoir. Monthly water outputs from the reservoir from 1997 through 1999, during months when water was released, ranged from 780 acre feet in January 1997 to 23 acre feet in October 1998.

Reservoir outflows are summarized in Table 5. Using these data and the corresponding total phosphorus concentrations, Regional Board staff calculated annual phosphorus outputs as 309 pounds in 1997, 161.9 pound in 1998, and 136.5 pounds in 1999. The latter figure, and the 1999 total outflow of 445 acre feet, were used in the TMDL source analysis and load allocations.

2. Potential minor phosphorus "sinks"

Other possible “sinks” (means of phosphorus export from ICR) include nutrients consumed and removed from the system by migratory birds and nutrients consumed by and removed in harvested trout. Phosphorus is also lost in particulate form by flushing of living plankton and particulate detritus in reservoir releases. During the 1970s and 1980s, some nutrients were removed through harvesting of aquatic weeds and raking of the shoreline to remove dead weeds and algae exposed after drawdown of the reservoir, but harvesting is not currently practiced. Some phosphorus from the water column may also be immobilized in the sediment either through burial by inorganic sediment or chemical precipitation. However, as discussed above, the assumption is being made that *all* P in the sediment will be available for plant growth over time unless steps are taken to remove or immobilize it.

Culp /Wesner/ Culp (1980) estimated that 834 afa of water is needed to replace evaporation and seepage losses at ICR. This amount takes into account an estimated 1,264 afa seepage loss, an estimated 385 afa evaporation loss, and an estimated 815 afa runoff gain. Infiltration was expected to decrease as the reservoir matured due to clogging of pores (USEPA, 1971). In evaluating the potential for groundwater contamination by wastewater stored in Harvey Place Reservoir, Jones & Stokes Associates (1983) noted that Indian Creek Reservoir is constructed of similar materials upon the same geologic formations, and that ICR had then "been in operation for nearly 20 years with a minimum of observed seepage". Phosphorus output from seepage and the other "minor sinks" mentioned above is considered *de minimis* and is not included in the TMDL calculations.

Section 3.4. Loading Capacity Linkage Analysis

"Loading capacity" is the maximum amount of a pollutant that a water body can assimilate and still meet its water quality standards. TMDL documents must describe the relationship between numeric targets and identified pollutant sources, and estimate the loading capacity for the pollutant of concern. The USEPA Region IX *Guidance for Developing TMDLs in California* (2000) states that the loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL, and that the linkage analysis section of the TMDL must

Table 9. Estimated Existing Phosphorus Loads to Indian Creek Reservoir from External and Internal Sources (rounded to the nearest pound)

Source	**Load (pounds per year) and % of total**

EXTERNAL SOURCES	
Precipitation	3
Direct surface runoff	68
Tributary inflow	43
Minor sources*	0
A. Total External Load	114 [24%]
INTERNAL SOURCES	
Total anoxic load (by literature formula for 120 day stratification period)	204
Total oxic load (by subtraction)	150
B. Total Internal Load (lb/yr)	354 [76%]
C. Loss in Reservoir outflow (lb/yr)	137
TOTAL LOAD (A +B)	468
NET WATER COLUMN LOAD (A + B -C)	331

*Loading and losses from the minor sources and sinks discussed in the text are considered *de minimis.*

discuss the methods and data used to estimate loading capacity.

A. Loading Capacity

The TMDL source analysis, loading capacity, and load allocation calculations for ICR use the reservoir area (110 acres) and volume (1515 af) associated with the "minimum pool elevation" of 45 feet required by agreement between STPUD and Alpine County. The loading capacity is the total phosphorus load contained in the water column at the target concentration (0.02 mg/L) and the "minimum pool" volume. Use of appropriate conversion factors gives a load of 82 pounds per year, rounded to the nearest pound. This represents a 75 percent reduction from the total estimated 1999 net *water column* loading of 330 pounds calculated using a mean annual concentration of 0.08 mg/L. (The difference between this figure and the 331 pounds net load in Table 9 results from rounding.)

B. Linkage Analysis

The USEPA's (1999) protocol document for development of nutrient TMDLs states::

> *"For lakes and reservoirs, a strong quantitative framework has been developed during the past two decades that allows for the prediction of algal biomass and other associated water quality parameters from nutrient loading and water column nutrient concentrations... . These concentration-response relationships are based on a large set of empirical data and have proven to be useful*

> *management techniques worldwide. For many lakes and reservoirs, the link between pollutant sources and water quality response required for TMDL development can be based on these relationships... ."*

The Indian Creek Reservoir TMDL uses these concentration-response relationships, based on empirical data, as the basis for the total P concentration target and for derivation of the loading capacity.

The proposed P concentration target represents a literature threshold between mesotrophic and eutrophic conditions. (It is the most conservative of several threshold figures cited in the USEPA's 1999 TMDL nutrient protocol document, and in other literature sources.) Mesotrophic conditions appear to be adequate to ensure protection of aquatic life and recreational uses and compliance with applicable narrative water quality objectives. Welch and Lindell (1980) state:

> *"apparently the rate of phosphorus loading that is apt to cause a eutrophic state from the standpoint of algal biomass and transparency is also similar to the loading that will cause an ODR [oxygen deficit rate] that is representative of eutrophy.... Therefore, the oxygen resources of a lake begin to be strained from the standpoint of the fishery at a P loading rate similar to that at which the recreational opportunities are impaired."*

Regarding recreational uses, Heiskary and Walker (1988, and summary in USEPA 1988) sampled phosphorus, transparency, and chlorophyll a in a number of lakes and compared the results with those of a lake user survey. (They emphasized that user perception is subjective and that users accustomed to oligotrophic lakes would probably have different opinions than those accustomed to eutrophic lakes.) The results of the study (summarized in Appendix 3) showed that a total P concentration of 20 parts per billion (0.02 mg/L) corresponded to a chlorophyll concentration which users associated with "scums evident" less than 10 percent of the time. The survey results also showed that this P concentration was found in waters rated "beautiful" for recreation and aesthetic enjoyment and on the borderline between "crystal clear" and "some algae". This concentration was associated with less than a 10 percent frequency of "definite algae" and "swimming impaired" (for aesthetic reasons). The Heiskary and Walker study did not address bacteria or other human health-related criteria which could affect the water contact recreation use.

Regional Board staff conclude, based on the literature review, that that the proposed numeric target and the associated loading capacity, if attained, will be adequate to protect designated aquatic life and recreational uses of ICR, the beneficial uses most likely to be impaired by eutrophication.

Section 3.5. TMDL and Load Allocations

TMDLs are the sum of "wasteload allocations" for point sources, "load allocations for nonpoint sources, and an explicit or implicit "margin of safety". Because the modeled total phosphorus loading to ICR is entirely from nonpoint sources, and no point source discharges are expected to be proposed in the future, the wasteload allocation is zero. the margin of safety, which is implicit, is discussed in Section 3.6.

As outlined above, the loading capacity, or "total maximum daily load" for ICR is 82 pounds per year of total phosphorus *in the water column* at the "minimum pool" gage height. (Additional P loading can occur but some P will exit in the outflow.) A 75 percent reduction in estimated existing loading from all sources is necessary to attain this loading capacity. Load allocations for nonpoint sources are discussed below and summarized in Table 12. Like the source analysis, the load allocations are based on inflows and outflows measured in 1999. They include consideration of background loading. No allocation is proposed for new or expanded phosphorus discharges in the watershed in the future, because land uses are not expected to change significantly (California Department of Water Resources, 1991). No load allocations are proposed for the minor sources of phosphorus discussed in Section 3.3, since these sources are assumed to be *de minimis.*

A. Load Allocations for External Sources

1. Precipitation.

The load allocation for direct precipitation on the reservoir surface is the same as the estimated existing load (3 lb/yr). Reduction of this load is not feasible, and because of its small size, reduction would make little difference toward attainment of the loading capacity. The application of BMPs in the "direct" and "tributary" watersheds may reduce the amount of particulate P in dust transported for short distances by wind and deposited in the reservoir via precipitation.

2. Direct Surface Runoff

The load allocation for surface runoff assumes that Best Management Practices (BMPs) with a phosphorus removal efficiency of 75% will be implemented to reduce phosphorus loading from the watershed directly tributary to ICR. The literature indicates that a reduction of this magnitude is feasible. Cooke *et al.* (1993) cite data from the National Urban Runoff Program showing that wet and dry detention basins can retain about 80 percent of suspended solids and produce about 47-68 percent retention of total P. Streamside buffer strips have been reported to reduce P loading from feedlots on a 4 percent slope by 67 percent (USEPA, 1988). Mean efficiencies of 64-71 percent for removal of P from stormwater by wetlands have been reported; under some circumstances a treatment efficiency as high as 95% can be reached (Moustafa, 1999). Table 10 shows reduction efficiencies for phosphorus removal modeled by the Chesapeake Bay Program (1998). The BMPs which could be used in the watersheds of Indian Creek Reservoir and its tributaries (e.g., stream protection with fencing, stream restoration, and shore erosion control) have projected phosphorus reduction efficiencies as high as 75 percent.

A 75% reduction in the existing surface runoff load (68 pounds per year) results in a load allocation of 17 pounds per year to this source. The load will be expressed as a ten year rolling average to account for seasonal and annual variability.

3. Tributary Inflow

The median total phosphorus concentration in the tributary inflow to ICR (Table 6) is about 0.03 mg/L. Since the background concentration of phosphorus entering the system from the West Fork Carson River is 0.02 mg/L, one third of the total tributary load to ICR is assumed to be controllable. The BMPs which could be used to reduce this load are the same types of BMPs, with the same efficiencies, discussed above for surface runoff. One third of the existing load from tributary inflow (43 pounds per year) is 14.3 pounds per year. A 75 percent reduction in this fraction leaves a load of 3.58 pounds per year. Adding this fraction to the estimated "background" tributary load (two thirds of the existing load, or 28.7 pounds per year) results in a load allocation to the tributary inflow of 32 pounds per year (rounded to the nearest pound). The load will be expressed as a ten year rolling average to account for seasonal and annual variability.

B. Load Allocations for Internal Sources

Estimated internal loading makes up about 76 percent of the current total phosphorus load to ICR, and a large reduction will be necessary to attain the target. Based on the estimated efficiency and longevity of P removal and inactivation treatments from the literature (Welch and Cooke, 1999) an 80-90 percent reduction in internal loading appears to be technically feasible. An 87 percent reduction was used to calculate the load allocation. Thirteen percent of the total internal load (354 lb/yr) is 46 lb/yr. Adding this to the mitigated external load of 52 lb/yr gives a total mitigated load of 98 lb/yr. Assuming that the outflow is included in the total internal load, and that a proportionate (87 percent reduction in the 1999 outflow load (137 lb/yr) occurs, 18 lb/yr of phosphorus will leave the reservoir, leaving a net load in the water column of 80 pounds/year, which is below the loading capacity of 82 pounds.

Table 11 summarizes data from literature case studies on some of the lake restoration techniques which could potentially be used for control of internal phosphorus loading in ICR. (The proposed TMDL implementation program, summarized in Section 5 of this staff report, does not prescribe specific phosphorus control measures, but rather establishes a process under which stakeholders will choose and implement controls.) Two of the methods which have been shown to provide long term reduction of internal phosphorus loading are alum treatment, with an efficiency up to 80%, and dredging, with an efficiency up to 90%. (The efficiency of dredging depends to a great extent on whether large amounts of nutrients will enter the lake from external sources after treatment.) For purposes of the load allocations, a phosphorus removal efficiency of 87% is assumed.

Table 10. Phosphorus Removal Efficiencies of Various BMPs Used in Modeling by the Chesapeake Bay Program (1998).

Category	BMP Type	Percent Efficiency
urban	erosion/sediment control	50
urban stormwater management	extended detention (dry)	20
	retention ponds (wet)	46
	stormwater wetland (one step)	47
	pond-wetland (series)	64
	sand filters	45
agriculture	rotational grazing	25
streambank protection	stream protection with fencing	75
	stream protection without fencing	40
	stream restoration	75
buffers	forested	70
	grassed	53
shoreline protection	structural shore erosion control	75
	nonstructural shore erosion control	75

Table 12. Load Allocations for Indian Creek Reservoir

Source	Load Allocation (lb/ yr)
EXTERNAL	
Precipitation	3
Direct Surface Runoff*	17
Tributary Inflow*	32
Total external allocation	*52*
INTERNAL	
Total internal allocation	46
OUTFLOW	18
Total Load Allocation	98
Net Load Allocation*	80

* Allocations for these parameters are interpreted as 10 year rolling averages to account for seasonal and annual variability.

** This allocation is to the water column, with the assumption that an additional 18 lb/yr of internally derived phosphorus will leave the reservoir in the outflow

Section 3.6. Margin of Safety, Seasonal Variations, and Critical Conditions

A. Margin of Safety

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in determining the relationship between discharges of pollutants and impacts on water quality. An explicit MOS can be provided by reserving (not allocating) part of the total loading capacity and therefore requiring greater load reductions from existing and /or future source categories. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The Indian Creek Reservoir TMDL includes an implicit margin of safety.

Sources of uncertainty in the analysis include: (1) interpretation of the narrative water quality objectives and of the threshold between mesotrophic and eutrophic conditions; (2) the lack of watershed- specific data on phosphorus loading from direct precipitation and surface runoff; (3) the inherent seasonal and annual variability in delivery of phosphorus from external sources and phosphorus cycling within ICR; and (4) simplifying assumptions made about the rate of P release from the sediment, the efficiency of BMPs in reducing P loading from external sources, and the efficiency of potential lake restoration methods.

The Indian Creek Reservoir TMDL provides an implicit margin of safety by:

<u>1) Interpreting compliance with standards (including beneficial use support and progress from eutrophic to mesotrophic conditions) through multiple targets and indicators.</u> The TMDL uses a range of indicators and target values, to measure compliance with standards and to account for areas where data (e.g., biological data) are scarce. The proposed total phosphorus concentration target (0.02 mg/L) is identified as the threshold between mesotrophic and eutrophic conditions in a number of recent literature sources, including sources cited in the USEPA's (1999) protocol document for development of TMDLs. The proposed target is the most conservative of a range of threshold values cited in the USEPA document and other literature. It therefore provides a margin of safety in comparison with a larger number. The phosphorus target is also within the range of literature values associated with full support of recreational uses (e.g., the Heiskary and Walker study excerpted in Appendix 3, and a State of Minnesota classification system which associates full support of "swimmable" uses with phosphorus levels of 25 to 30 ug/L in different ecoregions).

<u>2.) Incorporating conservative assumptions in the source analysis and development of load allocations.</u> Assumptions which provide a margin of safety include:

- Development of the TMDL for total phosphorus rather than for orthophosphate or "soluble reactive phosphorus", which are the forms of phosphorus most readily available to plants. The analysis assumes that <u>all P</u> in the system, including sediment P, will eventually be recycled and made biologically available. Because of the shallow depth of the organic sediment (about 6 inches), and the current pattern of summer stratification which leads to significant P release under anoxic conditions, this appears to be a reasonable assumption. For additional information, see the discussion of internal phosphorus loading in the Source Analysis section above.

- The "worst case" assumption that all phosphorus released from the sediment during summer stratification is made available for algal growth in the hypolimnion <u>during the summer</u>. See the discussion of the "Osgood Index" in the section of the

TMDL Source Analysis on internal loading of phosphorus.

B. Seasonal Factors and Critical Conditions

TMDLs must include consideration of seasonal and interannual factors and critical conditions. The USEPA's protocol for developing nutrient TMDLs (1999) defines "critical conditions" as "the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence."

All aquatic ecosystems, whether or not they have been affected by human activities, show seasonal and annual variations in the rates of nutrient input and internal cycling. Nutrient concentrations may be more important at certain times of the year. For example, in north temperate lakes, spring increases in water temperature and available solar radiation for photosynthesis can trigger spring algae blooms if adequate amounts of nutrients are present. The nutrients may be available during the winter, but low temperatures and short, cloudy days will inhibit blooms. Other symptoms of eutrophication such as dissolved oxygen depletion also vary seasonally or annually; impacts on beneficial uses are generally the most severe during the summer period thermal stratification and highest plant productivity. The impacts of eutrophication on aquatic life uses may vary with life stages of aquatic organisms; for instance, the juvenile stages of salmonids, including trout, require higher dissolved oxygen concentrations than adult fish.

At ICR, external phosphorus loading occurs mostly in the winter, due to California's wet winter/dry summer climate and the constraints of water rights (water to maintain the level of ICR is available only during the non-irrigation season). Phosphorus release from the sediment of ICR is probably greatest during the summer stratification season, and aerobic release of P from littoral sediments probably occurs during the warmer part of the year. Although fishing and other recreational uses occur year-round at ICR, the potential impact of eutrophication on recreational uses is also greatest in summer.

The TMDL for ICR accounts for seasonal and annual variations in external and internal phosphorus loading, and associated impacts on beneficial uses in several ways:

- The load allocations for surface runoff and tributary inflow are set as 10 year rolling averages to account for seasonal and annual variations in runoff, tributary flows, and phosphorus concentration.

- The most critical conditions for attainment of aquatic life and recreational uses in ICR occur during summer stratification, when the greatest release of phosphorus from the sediment occurs and warm temperatures promote depletion of oxygen in the hypolimnion. Attainment of the loading capacity will require removal or inactivation of phosphorus in the sediment of ICR. The shallow dimensions of the reservoir will continue to cause stratification, but reduced phosphorus loading will reduce the risk of oxygen depletion. (Better aeration, or oxygenation, of the hypolimnion is one method of reducing phosphorus release.)

Section 4. Public Participation

Federal TMDL regulations require that the public be allowed to review and comment on TMDLs. For TMDLs adopted as Basin Plan amendments in California, opportunities for public participation are provided through the procedures summarized in the USEPA Region IX *Guidance for Developing TMDLs in California* (2000), and through the California Environmental Quality Act (CEQA) review process. The Lahontan Regional Board maintains mailing lists for parties interested in receiving draft Basin Plan amendments and/or hearing notices, and a separate mailing list for its agenda announcements. The Basin Plan amendment and CEQA review processes include opportunities for written public comments and for testimony at a noticed public hearing. Written responses are required for written public comments received during the noticed public review period, and staff respond orally to late written comments and hearing testimony before Board action is taken. The Lahontan Regional Board's Basin Plan amendments (including draft TMDLs) are now made available on the Internet and publicized through press releases. Further opportunities for public participation are also provided in connection with review and approval of Regional Board-adopted Basin Plan amendments by the SWRCB and the USEPA. Documentation of public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony will be included in the administrative record of the Basin Plan amendments for USEPA review.

As outlined below, the implementation process will also involve coordination with public and private stakeholders in the California and Nevada segments of the Carson River watershed.

Section 5. Implementation and Monitoring

Section 5.1. Implementation Actions and Management Measures

Implementation of the TMDL is the responsibility of the STPUD (for control of internal phosphorus loading) and of the U.S. Bureau of Land Management, Alpine County, STPUD, and other land owners and land managers in the watershed (for control of external sources). The implementation program does not specify the means of compliance with the TMDL, but rather establishes a process for identification and implementation of controls for external and internal sources of phosphorus loading to ICR. (The Regional

Board is prohibited by Section 13360 of the California Water Code from specifying the manner of compliance with its orders.)

Implementation will be done in coordination with the following ongoing watershed planning and nonpoint source control efforts:

- The Regional Board's Watershed Management Initiative program for the Carson River watershed;

- Implementation of the recently revised statewide nonpoint source control plan (California State Water Resources Control Board, 2000) by the Regional Board and other stakeholders;.

- Implementation of the statewide Rangeland Water Quality Management Plan (California State Water Resources Control Board, 1995)

- The Upper Carson River Coordinated Resource Management Planning Group, which includes stakeholders in California and Nevada;

- The watershed planning effort for the entire Carson River watershed, which is being coordinated by the Nevada-based Carson Water Subconservancy District;

.

- Development of nutrient TMDLs for the Carson River by the State of Nevada.

Implementation is also expected to be coordinated with the U.S. Bureau of Land Management's planned update of its land management plan for the Indian Creek Reservoir Recreation Lands.

A. Implementation process

The implementation process will include the following:

1. For control of all sources:

Within 3-4 months after final approval of the TMDL, Regional Board staff will convene a stakeholder group for ongoing discussion of and communication about TMDL issues, including but not limited to STPUD, USBLM, and Alpine County staff and other public and private landowners in the watershed which contributes external phosphorus loading to ICR. Participation should also be invited from staff of the U.S. Natural Resource Conservation Service, the Alpine Resource Conservation District, and downstream stakeholders in California and Nevada, including the Nevada Division of Environmental Protection, the Upper Carson River CRMP group and the Carson Water Subconservancy.

2. For control of external loading:

- By 1 year after TMDL approval Regional Board staff and stakeholders will identify specific sites needing BMPs for phosphorus control within the watershed that contributes direct surface runoff to ICR.

- By 1 year after TMDL approval , Regional Board staff and stakeholders will identify specific sites needing BMPs for phosphorus control on public and private lands within the watershed tributary to the irrigation ditch which provides inflow to ICR from Indian Creek and the West Fork Carson River.

- By 2-3 years after TMDL approval, depending on progress toward "self determined" implementation of BMPs ("Tier 1" implementation under the statewide nonpoint source control plan), Regional Board staff will request reports of waste discharge to document the BMPs proposed for implementation. Staff will consider the need for conditional waivers ("Tier 2") or waste discharge requirements ("Tier 3") to ensure implementation of BMPs.

- Within 3-4 years after TMDL approval, BMPs will be implemented for source areas contributing to external loading of phosphorus to ICR. The statewide nonpoint source control plan (California State Water Resources Control Board, 2000) requires implementation of management measures for *agricultural* nonpoint sources by 2003, and management measures for all nonpoint sources by 2013.

3. For control of internal loading:

- Immediately after TMDL approval, Regional Board staff will use Porter Cologne Act Section 13267 authority to request a report from the STPUD on the method(s) it intends to use to reduce internal loading of phosphorus to ICR from the sediment.

- By 15 months after TMDL approval, STPUD will investigate the feasibility of controls for internal phosphorus loading to ICR and submit a plan for approval by the Regional Board. Depending upon the nature of the proposed action, the Regional Board may provide direction to staff for implementation, issue waste discharge requirements and/or a formal monitoring program for activities to control internal phosphorus loading, or take other appropriate action.

- By 4-5 years after TMDL approval STPUD will fully implement controls for internal phosphorus control.

B. Potential Implementation Measures

Potential implementation measures include Best Management Practices (BMPs) to control external sources of phosphorus loading, and in-lake measures to remove phosphorus-rich sediment or inactivate the internal phosphorus release process. During development of the TMDL, Regional Board staff conducted a literature review on BMPs and lake restoration methods. Information from this review is summarized in Tables 10 and 11. The CEQA document includes additional information on costs of BMPs.. Agricultural BMPs potentially relevant to control of external phosphorus loading to ICR include: Range and pasture management, proper livestock to land ratios, irrigation management, livestock waste management; fences (livestock exclusion); retention/detention ponds, constructed wetlands, streambank stabilization, sediment ponds; and riparian buffers (USEPA, 1999). Additional potentially relevant nonpoint source management measures, from the State Board's 2000 nonpoint source plan, include: education outreach, runoff control for existing development, road, highway and bridge runoff systems, marina and recreational boating management measures (including shoreline stabilization), instream habitat restoration, and vegetated treatment systems.

Further study will be necessary to identify the best and most cost effective in-lake phosphorus control method(s) for ICR, but based on the preliminary literature review, both phosphorus inactivation (by one of several chemical methods) and phosphorus removal (by dredging or bulldozing) appear to have the potential for rapid attainment of the numeric target. Other potential control methods, summarized in Table 11, include hypolimnetic withdrawal, hypolimnetic oxygenation (with more advanced technology than the historic aerators at ICR), biomanipulation, and treatment systems involving harvest of periphyton to remove nutrients. Regional Board staff recommend that, in addition to the selected in-lake treatment measure(s), STPUD should use the full amount of its existing water rights, under the constraints imposed by the Alpine Decree, in a manner which will maximize fresh water inflow into ICR.

To fulfill the requirement of California Water Code Section 13241 for disclosure of total costs of agricultural control programs, the CEQA document for the Indian Creek Reservoir TMDL provides rough estimates of total implementation costs for scenarios involving a specific combination of BMPs for external sources and dredging or alum treatment for internal sources. The total estimated cost of implementation assuming that the reservoir is dredged is about $1.5 million; the total cost assuming two alum treatments over a 20 year period is about $700,000.

C. Potential for Change in "Desired Future Conditions"

The implementation program outlined here assumes that Indian Creek Reservoir will continue to be maintained as a recreational fishery under the conditions of the Davis-Grunsky grant and current agreements between STPUD and Alpine County. There is some indication that, if TMDL implementation proves costly, STPUD and Alpine County may consider changing their agreements and ending freshwater input to the reservoir. (This is permissible under the Clean Water Act.) The reservoir would then receive input only from precipitation, surface runoff, and groundwater inflow. Since the reservoir was constructed over a natural ephemeral stream, surface water could be expected to be present at some time of the year. Assuming that the dams would not be removed, ponding of water from runoff might occur, and the reservoir site might gradually become a marsh or wet meadow. Jurisdictional wetlands, or the "reborn" ephemeral stream would still be considered waters of the state and of the U.S., with designated recreational and aquatic life beneficial uses. Recreational opportunities would probably not include fishing but could include the types of water contact and non-contact recreation activities associated with natural wetlands and ephemeral streams. Regional Board staff would need to evaluate the impacts of residual phosphorus from the reservoir on the beneficial uses of the wetlands and/or stream, and consider revisions in water quality objectives accordingly.

Section 5.2. Schedules for Implementation and Attainment

A. Schedule for Implementation

Target dates for completion of different components of the implementation program are summarized above. The proposed deadlines for completion of BMPs reflect the statewide nonpoint source plan's five year (2003) deadline for implementation of management measures for agricultural sources, and the 2013 deadline for implementation of management measures for all sources.

B. Schedule for Attainment

The time required for attainment of the narrative water quality objectives and the TMDL phosphorus target (which is more stringent than the current numeric objective), and for overall abatement of eutrophic conditions in ICR, will depend to a great extent on the method selected for control of internal phosphorus loading. The literature shows that alum treatment can reduce P concentration in eutrophic lakes and reservoirs dramatically within hours or days and maintain low P concentrations for up to 20 years, with an average of 10 years (Rydin *et al.*, 2000). Precipitation of phosphorus using calcium or iron compounds instead of alum also provides rapid, effective treatment, but the longevity of these methods has been less studied than that of alum treatment. Removal of sediment by dredging or bulldozing can also reduce ambient P concentrations relatively quickly. The time to target attainment with other methods such as hypolimnetic withdrawal, hypolimnetic circulation or aeration, biomanipulation, and "periphyton management" technology is less well defined. Regarding control of external sources, some BMPs (e.g., sedimentation basins) can be effective soon after completion; other BMPs (e.g.. revegetation) involve a lag period before they are fully effective. Attainment of the phosphorus target, and of mesotrophic conditions, is projected to occur by 2024, the end date in STPUD's agreement to maintain ICR as a fishery under the conditions of the Davis-Grunsky grant used for reservoir construction. Depending on the in-lake implementation measures used, attainment could occur sooner.

Section 5.3. "Reasonable Assurance" of Implementation

The USEPA's guidance for the development of TMDLs (1999, 2000) directs states to provide "reasonable assurance" that implementation activities will occur. The USEPA Region IX guidance (2000) cites a 1997 national policy

> "*that all TMDLs are expected to provide reasonable assurance that they can and will be implemented in a manner that results in attainment of water quality standards. This means that the wasteload and load allocations are technically feasible and reasonably assured of being implemented in a reasonable period of time. Reasonable assurance may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate*".

A. Authority for Implementation

The regulatory authority and stakeholder commitments which will affect the implementation of the TMDL are described below.

Lahontan Regional Board. The Regional Board has regulatory authority to enforce implementation of the TMDL under both the Clean Water Act and the California Water Code. The TMDL numerical targets themselves are not enforceable, except for those set at the level of water quality standards. Under Section 13360 of the California Water Code, Regional Boards cannot specify the design, location, type of construction or particular manner of compliance with Board orders. The Board does have the authority to adopt waste discharge requirements to ensure compliance with water quality standards (including support of beneficial uses) in Indian Creek Reservoir. Waste discharge requirements may also be conditionally waived. Waste discharge prohibitions allow the Regional Board to take direct and immediate enforcement action through issuance of cleanup orders even in the absence of waste discharge requirements, allowing timely response when nonpoint source pollution creates emergency conditions**.** The Board, or its Executive Officer, may also require water quality monitoring programs which specify monitoring of specific parameters, separately form water quality permits (Water Code

Section 13267). The Board's enforcement authority is summarized in Chapter 4 of the Basin Plan. As noted above, Regional Board staff intend to pursue implementation of the Indian Creek Reservoir TMDL under the "three-tier" approach of the revised statewide nonpoint source control plan (California State Water Resources Control Board, 2000). Water quality certification under Section 401 of the Clean Water Act may be required from the Regional Board for nonpoint source control activities which involve discharges or threatened discharges to wetlands or waters of the U.S. The Regional Board can also provide technical assistance and support applications by stakeholders for loans, grants, and/or other funding for implementation. Depending on the availability of resources, the Regional Board may be able to provide staff time for assistance with grant writing and contract management.

U.S. Bureau of Land Management (USBLM). The USBLM manages most of the land directly tributary to ICR through its Carson City, Nevada office. The USBLM will be responsible for implementing BMPs to control external loading of phosphorus from surface runoff to ICR. Indian Creek Reservoir is with in a priority watershed under the nationwide federal Clean Water Action Plan (CWAP). Under the CWAP, federal agencies are expected to cooperate with other stakeholders in watershed activities. The California State Water Resources Control Board has a Management Agency Agreement (MAA) with USBLM districts in California regarding the implementation of BMPs, and has stated its intent to update this MAA as part of implementation of the new statewide nonpoint source control plan. Regional Board staff will recommend that this update include provision for USBLM lands managed from Nevada, including the lands around ICR.

South Tahoe Public Utility District. STPUD has committed to maintaining ICR as a trout fishery through the original construction grant conditions, and through agreements with Alpine County. The District also maintains part of the diversion and conveyance facilities which provide inflow to ICR. STPUD is a "municipality" which is eligible to apply for Section 319 grants, State Revolving Fund loans, and other sources of state and federal funding available to local governments for watershed and water quality improvements.

Alpine County. Alpine County maintains the unpaved road which parallels one side of the reservoir, and controls the use of the $100,000/year mitigation funds paid by the STPUD under its agreements with the county. County permits might be required for the implementation of some types of BMPs on private lands. The County is also eligible to apply for grant and loan funds.

U.S. Forest Service, Humboldt-Toiyabe National Forest (Carson Ranger District). The Forest Service manages the upper reaches of the Indian Creek watershed. The Forest Service is one of the federal agencies affected by directives under the nationwide Clean Water Action Plan, and there is an existing MAA between the State Water Resources Control Board and the Forest Service regarding control of nonpoint source pollution from forest activities within California.

Other potential participants. Approval from the federal watermaster could be necessary for any changes in water rights or reservoir operating criteria which might be proposed as part of the implementation program. Permits from the U.S. Army Corps of Engineers and/or the California Department of Fish and Game could be required in connection with some types of implementation projects. The U.S. Natural Resource Conservation Service can provide technical and financial assistance for the implementation of BMPs on private lands.

The Carson River watershed, which includes ICR, is a priority watershed in the Regional Board's Watershed Management Initiative (WMI). The high degree of stakeholder cooperation and voluntary interest in watershed planning efforts in the Carson River watershed as a whole has resulted in its designation as a "National Showcase Watershed" under the CWAP. The participation of watershed groups may be especially helpful in leveraging funding for in-lake restoration, and volunteer labor may be available for activities such as revegetation in the watershed tributary to ICR.

B. Feasibility of Implementation

The BMPs and lake restoration measures reviewed by Regional Board staff and summarized this staff report and the CEQA document are technically feasible and have been shown to be effective in reducing phosphorus loading and/or abating eutrophic conditions. As outlined above, the Regional Board has the authority under the Clean Water Act and California Water Code to ensure implementation. The Board is committed under the USEPA-approved statewide nonpoint source control plan to ensure that agricultural management measures will be implemented in the Carson River watershed by 2003, and management measures for all nonpoint sources by 2013, whether or not the TMDL is approved.

The major uncertainties in evaluating the feasibility of implementation are political (see the "desired future condition" discussion above) and the availability of funding. The status of ICR as part of a CWAP watershed, and a priority WMI watershed, gives it high priority for a variety of funding sources for nonpoint source control and/or watershed restoration. In particular, CWAP status could be used by the USBLM to justify additional funding to fulfill its obligation to implement BMPs.

The USEPA has directed states to use part of their Section 319 nonpoint source grant funds for lake restoration activities which would also be eligible for Section 314 Clean Lakes grant funds, with the caveat that dredging projects will not be eligible in cases where external loading will soon negate the impacts of dredging. The situation at ICR is not comparable to that of larger reservoirs which are fed by natural streams with large phosphorus loads. Given applicable waste discharge prohibitions and the probability that current land uses will not change in the future, there is little potential for significant increases in external P loads to ICR. If current external sources were controlled and ICR were dredged to remove phosphorus rich sediment, low phosphorus concentrations in the reservoir could be expected to persist without the need for further dredging. Thus, dredging of ICR should be eligible for Section 319 grant funding. Section 319 grant funds could also be used to stabilize the unpaved county road and/or the portion of the tributary irrigation ditch system which is maintained by STPUD. The Alpine Resource Conservation District could also apply for Section 319 funds for BMP implementation on private lands.

Other potential sources of funding for nonpoint source control and/or reservoir restoration activities include low cost loans under the State Revolving Fund; the U.S. Natural Resource Conservation Service's cost sharing "EQIP" program, which also involves technical assistance; and the $100,000/year mitigation fee which STPUD pays to Alpine County. Additional potential funding sources are summarized in the USEPA's (1999) *Catalog of Federal Funding Sources for Watershed Protection*, and The Habitat Restoration Group's *Sources of Funds for Stream and Watershed Restoration in California*.

Section 5.4. Monitoring Plan

The proposed TMDL monitoring plan involves continuation of current monitoring by the STPUD of Indian Creek Reservoir and its tributary inflow. (Not all of the parameters sampled are necessary for determining compliance with TMDL load allocations.) Regional Board staff recognize that sampling stations and frequencies may need to be changed over time as a result of an adaptive management approach to implementation. Consequently, the Basin Plan amendments will <u>not</u> specify sampling locations and frequencies. The Regional Board's Executive Officer may adopt a formal monitoring program for ICR and its tributary inflow pursuant to the California Water Code, and changes in this program may be made over time without the necessity for further Basin Plan amendments.

The TMDL monitoring program is currently expected to involve:

- continued monitoring of tributary inflow and water quality (including P concentration)
- continued monitoring of ICR including gage height, water quality, and algal cell/colony counts
- continued monthly depth profile measurements in ICR including dissolved oxygen and temperature
- continued monthly measurements of total phosphorus concentrations at several depths including the hypolimnion
- continued monthly measurement of chlorophyll a at the near-surface depth
- continued monthly measurements of Secchi depth in ICR during the stratification period

- periodic inspections of BMPs, once they have been installed.

The phosphorus concentration and inflow amounts of precipitation and surface runoff to the reservoir will not be measured directly; the success of BMPs to reduce phosphorus runoff to ICR will be assessed through measurements of reservoir quality**.**

Additional studies which would be desirable if funding (e.g., Section 205(j) grant funding) becomes available include (1) quantification of phosphorus release from the sediment; and (2) a limnological study including biological sampling. Due to the uncertainty of funding, these studies are not being proposed as implementation measures in the Basin Plan amendments.

Section 6. Review and Revision of TMDL

The implementation program includes the deadlines outlined in Section 5.1, above. The monitoring program involves continuation of STPUD's current monitoring and reporting on water quantity and quantity in the reservoir and tributary inflow. Regional Board staff will continue to review monitoring reports on an ongoing basis, and will discuss them with STPUD and other stakeholders periodically. Comprehensive reviews of monitoring data and progress toward implementation and attainment of targets will be conducted at five year intervals. Because some of the targets and load allocations are expressed as ten year rolling averages to account for seasonal and annual variability, the first decision point on the need for revision of the TMDL will not occur until after the comprehensive review held in the tenth year. The use of 5 year intervals is supported by the work of Payne *et al*. (1991). These authors recommended long term monitoring to evaluate the success of lake restoration projects, due to the masking of lake improvement trends by interannual variability. They concluded that 5 years of pretreatment and 5 years of post-treatment data were needed to detect significant changes in trophic state.

Should the parties responsible for maintenance of Indian Creek Reservoir decide to change the "desired future state" as discussed in Section 5.1 above, the Regional Board would consider revising or rescinding the TMDL as appropriate. The timing of Basin Plan changes in this case would depend on the availability of staff resources.

List of Preparers

Hannah Schembri collected information on Indian Creek Reservoir from a variety of sources, analyzed and modeled the data, and developed source analysis, TMDL and load allocation numbers in cooperation with Judith Unsicker and Robert Dodds. Judith Unsicker developed final numbers and prepared the draft Basin Plan amendments and staff report using the information collected by Hannah Schembri and a review of readily available references on ICR and of the scientific literature. Dr. Ranjit Gill, former chief of the RWQCB's Southern Counties Unit, provided direction on the initial approach taken toward the TMDL. Robert Dodds, Assistant Executive Officer, and Alan Miller, current chief of the Carson/Walker watersheds unit, provided direction on later revisions.

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Appendix 1: Glossary

GLOSSARY

(The following definitions are taken largely from USEPA, 1999 and USEPA, 1988.)

Aerobic. Environmental conditions characterized by the presence of dissolved oxygen; used to describe biological or chemical processes that occur in the presence of oxygen.

Anoxic. Aquatic environmental conditions characterized by zero or little dissolved oxygen.

Benthic. Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.

Best management practices (BMPs). Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Biomass. The amount, or weight, of a species, or group of biological organisms, within a specific volume or area of an ecosystem.

Carlson trophic status index (TSI). Index based on the correlations between the clarity or transparency expressed by the Secchi disc depth, algal concentrations expressed by chlorophyll a, and the spring, or average annual total phosphorus concentrations. Identifies waterbodies as oligotrophic, mesotrophic, eutrophic, or hypertrophic.

Chlorophyll a. "Chlorophyll" is a group of green photosynthetic pigments. The amount of "chlorophyll a", a specific pigment, is frequently used as a measure of algal biomass in natural waters.

Epilimnion. See "Stratification".

Eutrophic. See "Trophic states"

Eutrophication. The process of physical, chemical and biological changes associated with nutrient, organic matter and silt enrichment and sedimentation of a lake or reservoir. If the process is accelerated by man-made influences, it is termed cultural eutrophication.

Hypolimnion. See "Stratification".

Macrophytes. Larger aquatic plants of all types. There are sometimes attached to the waterbody bottom (benthic) sometimes free-floating, sometimes totally submersed, and sometimes partially emergent. Complex types have true roots, stems, and leaves; the macroalgae are simpler but may have stem- and leaf-like structures.

Maximum depth. The greatest depth of a waterbody.

Mean depth. Volume of a waterbody divided by its surface area.

Mesotrophic. See "Trophic states".

Oligotrophic. See "Trophic states"

Periphyton. Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, piling and other structures.

Plankton. Group of generally microscopic plants and animals passively floating, drifting, or swimming weakly. Plankton include the phytoplankton (plants) and zooplankton animals).

Secchi depth. A measure of light penetration into a waterbody that is a function of the absorption and scattering of light in water. Secchi depth is operationally defined as the depth at which a white disk is indistinguishable from the surrounding water or the black and white quadrants of a black and white disk are indistinguishable from one another when the disk is lowered into the water. Standard Secchi disks are 20 cm in diameter; Secchi depth is measured in units of meters or feet.

Stratification (of waterbody): Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter, warmer water overlying heavier, cooler and more dense water. The upper layer is called the "**epilimnion";** the lower layer is the **"hypolimnion".**

Ten year rolling average. A ten year rolling average is the arithmetic mean of ten contiguous annual means. For example, in the tenth year, the mean of annual averages for years 1-10 will be calculated. In the eleventh year, a new mean, based on years 2-11 will be calculated, and so on.

Total phosphorus (Total P). The total amount of phosphorus in a sample, including both organic and inorganic forms. In most lakes, the organic forms of phosphorus make up a large majority of the total phosphorus.

Trophic state. A classification of the condition of a waterbody pertaining to the availability of nutrients. Trophic states include **oligotrophy** (nutrient poor), **mesotrophy** (intermediate nutrient availability), **eutrophy** (nutrient rich) and hypertrophy, or **hypereutrophy** (excessive nutrient availability). Increased availability of nutrients is generally correlated with increased biological productivity.

Unstratified. Indicates a vertically uniform or well-mixed condition in a waterbody. See also "Stratified."

Appendix 2: Summary of Carlson Trophic State Index

(Source: USEPA, 1999)

Appendix 3: Information Relevant to TMDL Indicators

(Source: USEPA, 1988)

Table 11. Comparison of Alternative Lake Restoration Methods (Cooke et al., 1993 and other references cited in Table)

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Dilution and Flushing- addition of low nutrient water and/or high volume water; dilutes P concentration; washes out algal cells.	Can control internal loading, algal biomass (including bluegreens which contribute to internal loading), increase clarity. Relatively low cost if water is available; immediate and proven effectiveness if limiting nutrient decreased. Dramatic improvements in Moses Lake, WA with a 10-20 percent per day water exchange with Columbia River water (EPA, 1988).	To be effective, flushing rate must approach or equal algal growth rate, Principle limitation is availability of low nutrient water. Potential adverse impacts on downstream waters from exported nutrients.	Variable from site to site depending on availability of water and cost of installing and maintaining distribution facilities and outlet structure (Cooke et al; USEPA 1988.)	Level of dilution and flushing under current water rights/operating criteria is inadequate to prevent eutrophication. Unless "new" water can be supplied (e.g. through a well) additional dilution/flushing probably not feasible.
Hypolimnetic Withdrawal -(release of nutrient rich/oxygen poor water from bottom of lake, through siphoning, pumping, or selective release rather than release from surface)	Relatively low capital and operational costs; effective in a large fraction of cases (maximum TP decreased; depth and duration of hypolimnetic anoxia decreased); potential long term and permanent effectiveness in increasing dissolved oxygen, reducing internal P loading.	Effectiveness depends on frequent interchanges of hypolimnetic water (several fold during the stratification period). Three to 5 years of total P export may be necessary to see an improvement in epilimnion quality. Potential adverse impacts on downstream water quality and uses from exported waters (with low DO, high P, and possibly high ammonia, hydrogen sulfide, and metals). Nuisance odor conditions may also occur.	Installation costs, (In 1990 dollars); for a 41 ha lake with 3.4 cubic meters/minute flow, \$304,000; for a 287 ha lake with 6.3 cubic meters/minute flow- \$45,000. (Indian Creek reservoir has a surface area of about 65 ha.)	Current water rights situation and operating criteria for ICR would not allow substantial releases of anoxic water during the summer when the reservoir is stratified..
Hypolimnetic aeration or oxygenation- Addition of compressed air or pure oxygen to bottom waters of lake during stratification.	Raises oxygen concentration without destratifying the water column or warming the hypolimnion; provides increased habitat and food for cold water fish; can reduce internal loading of P, NH4+, Mn, and Fe.	Effectiveness depends on proper design and sizing in relation to oxygen demand. May increase eddy diffusion of nutrients to epilimnion even if stratification is maintained. Works best for deeper waters (over 12-15 meters). Needs a large hypolimnion to work properly; use in shallow lakes and reservoirs should be viewed with caution (USEPA, 1988).	Dependent on equipment costs, power rates, cost of compressed air. In one case study, initial aeration cost was \$6500/ha for 6 months operation (\$3.40/kgO2). Another case study had a cost of \$2.50 /kg02. Long term costs (mostly operational) considered "relatively modest".	"Aerators" used at ICR did not add oxygen; see artificial circulation below.

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Artificial circulation (destratification)- injection of compressed air, or mechanical mixing devices	Enlarges habitat for aerobic animals; may reduce internal loading of P and decrease biomass of algae (especially blue-greens). Artificial destratification using bubble plumes reduced internal P loading in Chaffey Reservoir, Australia by about 85%. (Sherman, 1999).	Highly variable results from case to case (USEPA, 1988). Depending on sediment chemistry, may increase internal P loading. Temperature increase in hypolimnion may adversely affect cold water fish. Efficiency depends on air flow rate, depth at which air is released.	\$340-\$460/ha (1990 dollars) for installation and 1 year operation; annual costs \$320/ha (1990 dollars).	"Aerators" used for years at ICR to prevent winter ice formation; apparently did not prevent summer stratification / oxygen depletion.
Phosphorus Removal (Dredging or Drawdown and Scraping)	Rapid, long term decrease in internal nutrient loading and nutrient concentration in water column. Compared to P inactivation, does not introduce a "foreign" substance to the lake.	Must consider disposal site for dredged sediment and prevention of runoff from disposed sediment to surface waters, and sedimentation rate from external sources. Dredging can resuspend nutrients and toxic substances if present in sediment, create temporary odor problems (e.g. hydrogen sulfide), temporarily disrupt recreational uses, have temporary impacts on benthic biota. Drawdown and bulldozing could also temporarily affect recreational and benthic habitat uses and have temporary noise, dust, and traffic impacts.	(Cooke et al 1993) Median costs in 1991 dollars based on 9 case studies: \$ 17,984/ ha. Costs are lower if amortized over years of effectiveness; e.g., Lake Trummen, Sweden had an initial dredging cost of about \$5722/ha; the amortized cost over 25 years was \$229/ha/yr.	ICR probably has relatively low external sediment loading. which can be further reduced through BMPs. ICR sediment is fairly shallow (~6 inches in ___) compared to some lakes which have been dredged for restoration. Cooke et al identify dredging as the most reliable and permanent (although costly) solution to internal P loading if most nutrients are located in the top 0.3-0.5 meter of a sediment core.
Phosphorus Inactivation Using Alum Aluminum salts added to water, and produce a floc which precipitates P in the water column, then settles and provides a barrier to P release from the sediment..	Widely used; many case studies of effectiveness. Rapid, fairly long term (at least 10-15 years) decrease in internal nutrient loading and nutrient concentration in water column; increased transparency, reduced algal biomass. (USEPA 1988). Reduced P release up to 90 percent in laboratory experiments. Can reduce P loading from groundwater seepage as well as from internal recycling (Harper and Harvey, 1999). Sufficient floc may bury resting stages of benthic algal mats and limit future mat formation (Wagner et al, 1999). Apparent low or zero toxicity to aquatic biota with properly buffered applications.	Effects can be negated by high external nutrient loading and/or sedimentation which buries floc layer. If floc layer is too thin, benthic invertebrates can mix it with sediment, reducing effectiveness (Charboneau, 1999). Without adequate buffering (outside pH range of 6-8) , aluminum salts may be toxic . Less effective at removing organic P than inorganic P from water column. Temporary disturbance of recreational uses. Increased transparency may promote macrophyte spread (USEPA 1988).	Median cost of 9 case studies = \$564 ha.(1991 dollars) Cooke *et al.* cite amortized cost of one project which lasted 16 years as \$26.56/ha.	

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Phosphorus Inactivation Using Iron. Similar effects to those of alum, above.	Less concern about biotic impacts than for alum	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage.. Effects can be negated by high external nutrient loading. Would need to use aeration or artificial circulation (complete mixing) to maintain needed redox and pH conditions.		
Phosphorus Inactivation Using Calcium. Similar effect to those of alum, above.	Less concern about biotic impacts than for alum	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage. Effects can be negated by high external nutrient loading. May need to maintain alkaline pH to maintain effectiveness; would need aeration or complete mixing on a continual basis. .		
Phosphorus Inactivation using "Riplox" process. (Oxidation of top 10-20 cm of sediment through enhanced denitrification, improves P complexation with iron; prevents sulfate reduction)	Reduced sediment P release up to 90 percent in laboratory experiments; 50-80 percent reductions in lake case studies. Uses chemicals normally found in sediments; chemicals are placed directly in and largely confined to sediments. May last longer than alum treatment.	Fewer case studies than for alum to evaluate effectiveness, longevity; less guidance on dosage. Effects can be negated by high external nutrient loading. Assumes internal P loading due to iron redox reactions; if due rather to temperature and pH may not provide significant reduction. Chemicals must be applied with a special "harrow" device.	$5200/ha (1990 dollars). (Early case studies used experimental procedures.)	ICR sediment is relatively shallow (~6 inches, within cited 10-20 cm range of effectiveness of method.)

Method	Advantages	Disadvantages	Costs (from case studies)	Comments
Biomanipulation -Food web management (restructuring fish communities) to control algae.		Experimental; many interactions poorly understood, particularly in connection with small europhic lakes. (Such lakes may have significant macrophyte communities) Less precise than mechanical or chemical controls and requires knowledge of food web processes, which can be complex. May have unforeseen ecological consequences. Herbivores encouraged by food web changes may not be able to deal with filamentous bluegreen algae like those present at ICR	Depends on means used to change fish community/control existing fish (drawdown, rotenone, netting, etc.) . Manipulation may be required on a permanent basis in order to make effects last.	Available case studies (mostly eastern U.S. and Europe) do not involve the fish species present in ICR.
Periphyton management- Nutrient rich water to grow attached algae as it flows over a substrate; algae are harvested to remove nutrients from system.	Relatively "low tech"; high nutrient removal efficiency under certain circumstances. (DeBusk et al., undated).	Would require maintenance; presence of structures at ICR could detract from recreational experience; efficiency under conditions at ICR not known; disposal site would be needed for algae/nutrients.		
"Pretreatment"- Use of wetlands,detention basins or upstream reservoirs to remove nutrients in inflow to lakes/reservoirs.	Reduces external loading; wet detention basins provide 47-68% removal of total P. Wetlands- up to 83 % removal of P. Jordanelle Reservoir on Provo River, UT reduced downtream P by about 25% (Miller and Cutler, 1999).	Would not address internal loading at ICR. Wetlands may release P at certain times of year. Treatment facilities could require maintenance such as sediment removal from basin, harvesting of vegetation from wetland.	Depends on size and maintenance requirements.	

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION INCORPORATING

A TOTAL MAXIMUM DAILY LOAD AND IMPLEMENTATION PLAN TO CONTROL SEDIMENT LOADING TO HEAVENLY VALLEY CREEK, EL DORADO COUNTY, CALIFORNIA

California Regional Water Quality Control Board
Lahontan Region
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November 2000

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PROPOSED AMENDMENTS TO THE *WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION*

I. INTRODUCTION TO NEW SECTION OF BASIN PLAN IMPLEMENTATION CHAPTER CONCERNING TOTAL MAXIMUM DAILY LOADS

A new Section 4.13 of the Basin Plan's implementation chapter will be created with the following introductory language. TMDLs and TMDL implementation plans for specific water bodies and pollutants will be added to this section as they are approved.

"4.13 TOTAL MAXIMUM DAILY LOADS

Section 303(d)(1) (A) of the Clean Water Act requires that "Each State shall identify those waters within its boundaries for which the effluent limitations... are not stringent enough to implement any water quality standard applicable to such waters. The Clean Water Act also requires states to establish a priority ranking for waters on the Section 303(d) list of impaired waters and to establish Total Maximum Daily Loads (TMDLs) for such waters. TMDLs are essentially strategies to ensure the attainment of water quality standards in impaired waters.

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the Clean Water Act. A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the "loading capacity") is not exceeded. TMDLs are also required to address seasonal variations and to include a margin of safety to address uncertainty in the analysis. In addition, federal regulations (40CFR 130.6) require states to develop water quality management plans to implement water quality control measures including TMDLs.

The U.S. Environmental Protection Agency (USEPA) is required to review and either approve or disapprove the TMDLs submitted by states. If the USEPA disapproves a TMDL submitted by a state, the EPA is required to establish a TMDL for that water body. Upon establishment of the TMDL by the USEPA, the state is required to incorporate the TMDL, along with appropriate implementation measures, into the state water quality management plan.

This section of the Lahontan Basin Plan contains Total Maximum Daily Loads (TMDLs) for specific water bodies and pollutants. Future TMDLs will be added as they are approved. Background information used to develop each of the specific TMDLs will be retained with the administrative record of the Basin Plan amendments, and will be available to the public on request."

II. TOTAL MAXIMUM DAILY LOAD AND IMPLEMENTATION PLAN FOR HEAVENLY VALLEY CREEK, EL DORADO COUNTY, CALIFORNIA

The proposed Basin Plan language below will be added to the new Section 4.13 of the Basin Plan implementation chapter. Final Basin Plan revisions will include appropriate changes to the "record of amendments" page and the Table of Contents, List of Figures, Index, bibliography, page numbers and headers to reflect the new material. Final locations of tables in relation to text may be changed to accommodate the Basin Plan's two-column format.

"Heavenly Valley Creek, El Dorado County

Introduction: Heavenly Valley Creek is a tributary of Trout Creek in the southern portion of the Lake Tahoe watershed. The segment of Heavenly Valley Creek within the permit boundaries of the Heavenly Ski Resort is impaired by sedimentation related to historic ski resort development (including roads and ski runs). Sedimentation of Heavenly Valley Creek is of concern not only because of its impacts on instream uses but also because of its cumulative contribution to the degradation of Lake Tahoe. All of the subwatershed affected by the Total Maximum Daily Load (TMDL) for sediment is National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit (LTBMU) and within the permit boundaries of the Heavenly ski resort.

The LTBMU has modeled sediment delivery to Heavenly Valley Creek, and reductions in sediment loading expected as a result of ongoing erosion control work. This TMDL is based on LTBMU modeling and monitoring data. The TMDL implementation program is based substantially on continuation of existing erosion control and monitoring programs which are being carried out under an adaptive management approach by the LTBMU and the ski resort. Progress toward attainment of water quality standards in Heavenly Valley Creek will be evaluated in relation to monitoring data for Hidden Valley Creek, another tributary of Trout Creek with an undisturbed watershed within National Forest lands. A Regional Board staff report (California Regional Water Quality Control Board, Lahontan Region, 2000) provides the technical information supporting the regulatory elements of this TMDL.

Problem Statement: The water quality standards of concern in relation to this TMDL are beneficial uses related to aquatic life (COLD, RARE, MIGR, and SPWN; see Chapter 2 of this Basin Plan), and narrative water quality objectives for sediment, settleable materials, suspended sediment, and nondegradation (see Basin Plan Chapter 5). Ski resort development began in the Heavenly Valley Creek watershed in 1956, and there is evidence of significant sediment-related impacts on water quality and beneficial uses in the early 1970s, before adoption of the North Lahontan Basin Plan. The creek has been significantly affected by hydromodification (including a snowmaking reservoir and diversion of part of the creek into a culvert). Monitoring data show that the creek has elevated suspended sediment concentrations and loads compared to the reference stream.

Problems have been identified with stream channel stability, and the creek has been rated as "marginal" fish habitat since 1982.

Numeric Targets: A variety of targets and indicators, reflecting both instream and hillslope conditions, have been selected for the TMDL. They are summarized in Tables 4.13-HVC-1 and 4.13-HVC-2. In some cases they incorporate hillslope restoration targets established independently by the LTBMU during development of a master plan for the ski resort (TRPA, 1995, 1996). As used in the targets, the loading capacity, and load allocations, the term "5 year rolling average" means the arithmetic mean of 5 contiguous annual means. For example, in the fifth year, the mean of annual averages for years 1-5 will be calculated. In the sizth year, a new mean, based on data for years 2-6 will be calculated, and so on.

Table 4.13-HVC-1. Instream Indicators and Targets, Heavenly Valley Creek TMDL

Indicator	Target Value(s)
Suspended Sediment	
Suspended sediment concentration	Concentration no greater than annual average for Hidden Valley Creek during a year with similar precipitation and runoff.
Instream Total Sediment Load	Maximum 53 tons/year as a 5 year rolling average.
Geomorphology Measures	
Pfankuch channel stability rating (composite rating includes numeric scores for 15 different indicators)	Increasing trend over time from "fair-poor" to "good" (comparable with overall rating of Hidden Valley Creek)
USFS Region 5 "Stream Condition Index" (SCI)	Improving trends in channel morphology over time
Biological Indicators	
Macroinvertebrate community health.	Improving trends in benthic invertebrate community metrics over time, approaching conditions in Hidden Valley Creek

Table 4.13-HVC-2. Hillslope Indicators and Targets, Heavenly Valley Creek TMDL

Indicator	Target Value(s)
Percent Equivalent Roaded Area (ERA)	LTBMU targets and schedules for ERA reduction for ski run and road categories and for watershed as a whole; progress reported annually and evaluated at 5 year intervals.
Effective soil cover (vegetation, woody debris, organic matter, rocks) on ski runs and roads	Cover meets modeled mitigation targets set for specific road/run segments in watershed, and overall cover rating is "good" or better using LTBMU evaluation criteria.

Source Analysis: Modeled sediment delivery from various hillslope source categories to Heavenly Valley Creek is shown in Table 4.13-HVC-3. With the assumptions that instream bedload sediment constitutes 20 percent of the total, and that hillslope sources contribute proportionately to instream loading, Regional Board staff used modeled hillslope sediment delivery rates and monitored instream suspended sediment and flow data to estimate instream sediment loading as shown in Table 4.13-HVC-4. Natural sediment loading in Hidden Valley Creek is included for reference.

Table 4.13-HVC-3. Modeled Sources of Sediment Delivery to Heavenly Valley Creek. (Sediment delivery figures are for the 1341 acre watershed.)

Source Category	**Area (acres)**	**Sediment Delivery (tons/year)**	**Percent of Total Load**
Roads	19	349	62
Ski Runs	182	176	32
Impervious surface	1	0*	0*
Undeveloped Area	1119	34	6
TOTAL	**1341**	**559**	**100**

* Sediment delivery from impervious surface is considered "de minimis".
** Number rounded upwards

Table 4.13-HVC-4. Source Analysis for Instream Total Sediment Loading to Heavenly Valley and Hidden Valley Creeks (Values are rounded to the nearest ton.)

Source Category	**Loading (Tons/Year)**	**Percent of Total Load**
Heavenly Valley Creek		
Roads	93	62
Ski Runs	48	32
Undisturbed Lands	9	6
Impervious Surface	0*	0
TOTAL	150	100%
Hidden Valley Creek		
Undisturbed Lands	45	100%
TOTAL	45	100%

* Sediment delivery from impervious surface is considered "de minimis".

Loading Capacity/Total Maximum Daily Load and Linkage Analysis: The loading capacity for total annual instream sediment loading to Heavenly Valley Creek, measured at the "property line" station near the resort permit boundaries, is 53 tons of sediment per year, expressed as a 5 year rolling average. After consideration of differences in watershed size, this figure is reasonably close to the estimated 45 tons/year total sediment load in the reference stream, and reflects the modeled maximum achievable reduction in hillslope sediment loading, assuming the application of Best Management Practices to all disturbed areas in the watershed. (See the discussion of load allocations below.) Because the wasteload allocation is zero and the TMDL margin of safety is implicit, the loading capacity is also the Total Maximum Daily Load.

It is difficult to predict precise relationships between hillslope sediment delivery and instream conditions because these linkages are often indirect (e.g., temporal and spatial lags between erosion and instream impacts) and because of the seasonal and annual variability in ecosystem processes. This TMDL uses an "inferred linkage" based on comparison of conditions in Heavenly Valley and Hidden Valley Creeks, and a literature review, summarized in the staff report, which indicates that the numeric target will adequately protect aquatic life uses. Compliance with standards will be measured through long term evaluation of all of the numeric targets and indicators in Tables 4.13-HVC-1 and 4.13-HVC-2. If these targets are attained, erosion rates and sediment delivery should decline to levels which will allow instream habitat and beneficial uses to recover, over time, from the impacts of excessive sedimentation in the past.

Wasteload Allocations: There are no point source of sediment to the Section 303(d) listed segment of Heavenly Valley Creek, and the wasteload allocation for point sources is zero.

Load Allocations: Assuming a 1:1 relationship between hillslope sediment delivery and total instream sediment load, the loading capacity is allocated to hillslope sediment source categories in proportion to their percent contributions to the existing sediment load. Allocations are shown in Table 4.13-HVC-5. The allocation for new development is based on LTBMU modeling data and reflects estimated loading after full application of BMPs.

Table 4.13-HVC-5. Instream Load Allocations for total sediment in Heavenly Valley Creek

Source Category	**Load Allocation (tons/year as a 5 year rolling average)**	**Percent of Total**
Roads	28	53
Ski Runs	11	21
New Development	0.7	*
Undisturbed lands	14	26
Impervious surface*	0	0
TOTAL	53.7**	100%**

*The contribution of impervious surface to sediment loading is considered *de minimis.*
** The discrepancy between the total load allocations and the loading capacity (53 tons/year) is considered to be within the margin of error of the calculations.

Margin of Safety. The TMDL includes an implicit margin of safety to account for uncertainty in the analysis. Sources of uncertainty include: interpretation of compliance with standards, including narrative objectives and beneficial use support; limited data available for some indicators; limitations of the LTBMU sediment delivery model, and inherent seasonal and annual variability in sediment delivery and instream impacts of sediment.

The TMDL provides a margin of safety by: 1) interpreting compliance with standards through multiple, dynamic targets and indicators; 2) incorporating conservative assumptons in the soruce analysis and development of load allocations; and 3) incorporating a rigorous monitoring and review program and schedule which provides an ongoing mechanism to adjust the TMDL if adequate progress toward attainment of standards is not being made.

Seasonal Variations and Critical Conditions. The TMDL uses multiple numeric targets and indicators in order to integrate the net cumulative effects of sedimentation over longer time frames. The hillslope sediment delivery target, the loading capacity, and the load allocations are expressed as 5 year rolling averages to account for natural seasonal and annual variation in sediment loads, with the recognition that trends may not be apparent within shorter time frames. Other numeric targets are also expressed as long term trends. The TMDL and load allocations are set at levels which, over time, will allow instream aquatic habitat to recover to a level which adequately supports aquatic life uses.

Implementation Measures and Schedule. Implementation is the responsibility of the U.S. Forest Service, Lake Tahoe Basin Management Unit (the landowner) and the Heavenly Ski Resort (an LTBMU permittee). The program of implementation summarized in Table 4.13-HVC-6 is based primarily on continuation of the existing LTBMU erosion control program which requires application of Best Management Practices to all disturbed areas in the ski resort under an adaptive management approach. The implementation program includes full application of Best Management Practices to all new and existing disturbed areas within the ski resort. Implementation also include the monitoring and review and revision programs discussed below.

The Regional Board will use its existing authority, including the Lake Tahoe Basin control measures outlined in Chapter 5 of this Basin Plan, and the three-tier compliance approach (ranging from voluntary compliance to regulatory action) in the statewide Nonpoint Source Management Plan, to ensure implementation of the TMDL. If needed, the Regional Board will use enforcement orders to ensure implementation. The LTBMU and the Tahoe Regional Planning Agency have authority, and have made commitments, to ensure implementation in the Nevada portion of the Heavenly Valley Creek watershed.

Erosion control work within the Heavenly Valley Creek watershed is expected to be complete by 2006. The consequent reduction in hillslope sediment delivery is expected to allow recovery of instream physical conditions to more natural levels, leading to gradual recovery of aquatic life uses. Attainment of instream standards is projected to occur within 20 years after final approval of the TMDLs (by 2021). The technical staff report includes additional information on authority for and commitments to implementation, and demonstrates that there is reasonable assurance of continued implementation and attainment of standards.

Monitoring: The TMDL monitoring program will focus on the indicators listed in Tables 4.13-HVC-1 and 4.13-HVC-2. With the exception of macroinvertebrate community health, all of these indicators are already being monitored as part of the LTBMU's adaptive management program. Most of these indicators are sampled annually;

Table 4.13-HVC-6. Summary of TMDL Implementation Program

Implementation Measure	Schedule
Abandon and restore 7.59 acres of existing unpaved roads	Complete by 2006
Stabilize 21.10 acres of existing roads which will remain in use	Complete by 2006
Restore 182 acres of existing ski runs	Complete by 2006
Maintain BMPs as necessary	Annually
Review success of specific BMPs at specific sites; identify and implement improvements through adaptive management approach	Annually
Conduct a comprehensive review of progress toward watershed restoration and attainment of water quality standards and identify needs for change through adaptive management program.	At five year intervals beginning in 2000

surveys for others, such as the Pfankuch stream channel condition index, are conducted at longer intervals to detect long term trends. TMDL monitoring will include stations in both the Heavenly Valley Creek and Hidden Valley Creek watersheds. The technical staff report for the Heavenly Valley Creek TMDL includes recommendations for sampling locations and frequencies. However, because of the adaptive management approach to implementation, and the pending completion of the first comprehensive review of five years of monitoring data, this TMDL allows flexibility for modification of the monitoring program over time. No later than 120 days after the final approval of the Heavenly Valley Creek TMDLs, Regional Board staff will reach agreement with LTBMU and Heavenly ski resort staff on initial sampling frequencies and locations for all of the TMDL numeric indicators. This agreement may be formalized either through a Memorandum of Understanding or through modifications to the monitoring program in the waste discharge requirements for the Heavenly ski resort.

Results of the TMDL monitoring will be reported in the annual reports produced by the LTBMU as part of its adaptive management program for the Heavenly ski resort as a whole, and in the projected comprehensive evaluations for this program which are to be produced at five year intervals beginning in 2000.

Schedule for Review and Revision of the TMDL: Regional Board staff will continue to participate in the interagency technical advisory group for the LTBMU's erosion control and monitoring programs. Staff will review the annual and five year monitoring and evaluation reports described above from the perspective of progress toward implementation of controls necessary to meet the load allocations, and toward attainment of water quality standards. If significant progress is not apparent at the conclusion of the second (2005) review, Regional Board staff will evaluate the need for revision of the TMDLs and/or the implementation program. "

Bibliography

The following references will be added to the Basin Plan bibliography. Addition of these citations is not meant to imply incorporation by reference.

California Regional Water Quality Control Board, Lahontan Region, 2000. *Technical Staff Report: Total Maximum Daily Loads for Sediment and Implementation Plan, Heavenly Valley Creek, El Dorado County, California.*

Tahoe Regional Planning Agency, 1995, 1996. *Draft and Final Environmental Impact Report/Statement, Heavenly Ski Resort Master Plan, 5 volumes.*

DRAFT ENVIRONMENTAL DOCUMENT

FOR

Basin Plan Amendments
Concerning

TOTAL MAXIMUM DAILY LOAD AND IMPLEMENTATION PLAN FOR SEDIMENT LOADING TO HEAVENLY VALLEY CREEK, EL DORADO COUNTY

STATE CLEARINGHOUSE # 98092052

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SUMMARY

The Lahontan Regional Water Quality Control Board proposes to adopt Basin Plan amendments to incorporate a Total Maximum Daily Load (TMDLs) and a TMDL implementation program, for Heavenly Valley Creek, a tributary to Trout Creek within the Lake Tahoe Basin which is impaired by sedimentation. The TMDL would set limits for instream sediment loading to the creek from roads, ski runs, and undeveloped areas within the Heavenly Ski Resort boundaries, and would include other indicators and targets to measure attainment of water quality standards related to sediment. The TMDL implementation program would involve continuation of ongoing watershed restoration work and monitoring by the U.S. Forest Service and the Heavenly ski resort, and some additional monitoring to document the success of restoration. This environmental document concludes that the proposed Basin Plan amendments will not have any significant impacts on the environment.

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Regional Board) is the California State agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Regional Boards which function as part of the State Water Resources Control Board (SWRCB) system within the California Environmental Protection Agency. The Lahontan Regional Board implements both the federal Clean Water Act and the Porter-Cologne Water Quality Control Act, which is part of the California Water Code. Water quality standards and control measures for waters of the Lahontan Region are contained in the *Water Quality Control Plan for the Lahontan Region* (Basin Plan). The Lahontan Regional Board proposes to amend the Basin Plan to incorporate a "Total Maximum Daily Loads" (TMDL) and an implementation plan to address sedimentation problems related to ski resort development in the watershed of Heavenly Valley Creek, within the Lake Tahoe Basin in El Dorado County. (A small part of the Heavenly Valley Creek watershed is within the state of Nevada.) The amendments also include a short introduction to a new section of the Basin Plan which will contain the Heavenly Valley Creek TMDL and future TMDLs for other water bodies as they are approved.

The basin planning programs of the SWRCB and the nine Regional Boards have been certified by the California Secretary for Resources under CEQA Section 21080.5 as “functionally equivalent” to the preparation of an Environmental Impact Report (EIR) or Negative Declaration. This certification means that the Regional Board can prepare relatively short “functional equivalent environmental documents,” rather than lengthy EIRs, to meet CEQA requirements for Basin Plan amendments. “Functional equivalent” documents must still contain all of the legally required components of “normal” CEQA documents, and must meet CEQA requirements for public participation. The CEQA analysis below concludes that the adoption of the proposed Basin Plan amendments will not have any new significant environmental impacts (defined as physical changes in the environment). Therefore, this staff report should be considered the functional equivalent of a Negative Declaration. The technical background for the proposed TMDL and implementation program is contained in a separate staff report (California Regional Water Quality Control Board, Lahontan Region, 2000) which is available on request from the Board's South Lake Tahoe office. The report will also be made available on the Internet at: <http://swrcb.ca.gov/rwqcb6/>.

PROJECT DESCRIPTION

Under Section 303(d) of the Clean Water Act, the Regional Board is required to identify surface waters which are not meeting water quality standards and are not expected to do so even with the use of technology-based controls. For Section 303(d)-listed waters, the Regional Board must develop strategies called “Total Maximum Daily Loads” (TMDLs). TMDLs involve calculation of pollutant loads from all point and nonpoint sources in the watershed, and determination of the reductions in pollutant loads from each of these sources, which, when considered together with a “margin of safety,” are necessary for attainment of standards. TMDL implementation programs are required under 40CFR 230.6 and the California Water Code, and California TMDLs and implementation programs must be adopted as Basin Plan amendments.

Heavenly Valley Creek is a tributary of Trout Creek, which joins the Upper Truckee River just above its confluence with Lake Tahoe. The segment of Heavenly Valley Creek within the boundaries of the Heavenly ski resort (a U.S. Forest Service permittee), is Section 303(d)-listed for sedimentation problems related to historic watershed disturbance for resort development and maintenance. Sedimentation of Heavenly Valley Creek is of concern not only because of its impact on instream beneficial uses, but also because of its cumulative contribution to the degradation of Lake Tahoe through addition of sediment and sediment-bound nutrients.

The proposed amendments are based largely on past modeling of sediment loads and feasible loading reductions by the U.S. Forest Service, Lake Tahoe Basin Management Unit (USFS), on monitoring data collected for Heavenly Valley Creek and a reference stream during the 1990s, and on watershed restoration and monitoring programs which have been approved by the USFS and Tahoe Regional Planning Agency (TRPA). These programs are being implemented under the 1996 Heavenly Ski Resort Master Plan (TRPA, 1995, 1996). The TMDL implementation program includes monitoring of additional indicators to measure the success of the program in ensuring compliance with water quality standards.

The proposed amendments also include a short introduction to a new Section 4.13 of the Basin Plan’s implementation chapter. The Heavenly Valley Creek TMDL and future TMDLs for other water bodies in the Lahontan Region will be added to Section 4.13. The amendments will also include changes to the Basin Plan's Table of Contents, List of Tables, "Record of Amendments" page, index, bibliography, and page numbers, as appropriate. The Basin Plan amendments incorporating the TMDL will include: 1) a problem statement which summarizes historic violations of water quality standards; 2) a variety of instream and hillslope numeric targets and indicators; 3) a quantitative estimate of nonpoint sources of sediment loading to Heavenly Valley Creek; 4) an analysis of the relationship between hillslope sediment production processes and effects on instream water quality and beneficial uses; 5) "load allocations" setting maximum limits for instream total sediment loading in relation to hillslope sources; 6) summaries of the implicit margin of safety incorporated into the TMDL and the manner in which the TMDL accounts for seasonal variation and critical conditions; 8) summaries of the implementation and monitoring programs; and 9) provisions for review and revision of the TMDL.

The "loading capacity" or "total maximum daily load" is set at 53 **tons of sediment/year** in Heavenly Valley Creek, at the "property line" monitoring station, expressed as a 5 year rolling average. This figure is based on an assumed overall 65 percent reduction from modeled historic sediment loading. The reduction is achievable from past and planned application of Best Management Practices to all disturbed areas in the affected portion of the watershed. It is considered reasonably close to estimated sediment loading in the reference stream (45 tons per year), considering that the watershed area of the reference stream is only about 87 percent of that of Heavenly Valley Creek. The loading capacity is divided into numeric load allocations for unpaved roads, ski runs, undeveloped areas, and projected new development in the watershed. There are no point sources of sediment in the affected watershed, and the TMDL "wasteload allocation" is zero. The margin of safety for the TMDL was provided by 1) interpreting compliance with standards through multiple, dynamic targets and indicators; 2) incorporating conservative assumptions in the source analysis and load allocations, including setting load allocations reasonably close to reference conditions; and 3) incorporating a rigorous monitoring and review program which will allow adjustment in of the TMDL in the future if standards are not attained.

The TMDL implementation program relies on completion of ongoing erosion control work within the Heavenly ski resort. This includes both the restoration work identified in the 1995-96 environmental analysis for the Heavenly Ski Resort Master Plan (Tahoe Regional Planning Agency, 1995, 1996) and the U.S. Forest Service's required retrofit of Best Management Practices (BMPs) to all disturbed areas within the watershed (Sherry Hazelhurst, personal communication). Retrofit of BMPs is required for all development in the Lake Tahoe Basin; see Chapter 5 of the Lahontan Basin Plan (California Regional Water Quality Control Board, 1995). The TMDL implementation program includes monitoring and reporting on the numeric indicators and targets. Implementation also includes provisions for review of monitoring results and progress toward attainment of standards, and revision of the TMDL and implementation programs if appropriate.

REQUIRED APPROVALS

Following their adoption by the RWQCB, the proposed Basin Plan amendments must be approved by the California State Water Resources Control Board (SWRCB) and the California Office of Administrative Law. The Clean Water Act requires that TMDLs be approved by the U.S. Environmental Protection Agency (USEPA). No other agencies are expected to use this CEQA document as the basis for project approvals.

ENVIRONMENTAL AND SOCIOECONOMIC SETTING

The TMDL affects only the upper portion of the Heavenly Valley Creek, within the Heavenly ski resort boundaries on National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit (LTBMU). Part of the watershed is within the state of Nevada and drains toward California. However, there are no mapped surface waters within this area, and the model used to develop the TMDL source analysis and load allocations does not distinguish between California and Nevada sources. Separate load allocations have not been made by state. Adequate authority and commitments to implementation (discussed in the technical staff report) exist to provide reasonable assurance of implementation in both states.

Heavenly Valley Creek is located in the Carson Range, east of the Sierra Nevada crest in the southeastern portion of the Lake Tahoe watershed (Figure 1). The listed segment of the creek has a drainage area of 1,341 acres (including about 57 acres in Nevada), and an approximate length of 2.7 miles within the resort boundaries. The creek's elevation change is 3,400 feet (from 9,080 feet to 6,255 feet at its confluence with Trout Creek); and its average gradient is 20 percent. Heavenly Valley Creek flows for about one mile outside of the ski resort boundary before joining Trout Creek.

Progress toward attainment of standards in Heavenly Valley Creek will be evaluated in relation to monitoring data for a reference stream, Hidden Valley Creek, another tributary of Trout Creek (Figure 1). This creek has a watershed area of 1162 acres above the monitoring station. The streamflow and watershed characteristics of Hidden Valley Creek are similar to those of Heavenly Valley Creek, but the watershed is undisturbed.

Soils within the Heavenly ski resort boundaries are highly erodible, excessively well drained, and contribute to high peak discharges during rainstorms or spring runoff. Soils are derived from granitic parent material, in all stages of decomposition. Once disturbed, soils at Heavenly are difficult to revegetate because of low fertility and harsh climatic conditions. Under the Bailey land capability system used in the Lake Tahoe Basin, most of the lands within the Heavenly Valley Creek watershed are capability Class 1 or 2 and would be allowed only 1 percent impervious surface coverage or permanent soil disturbance under current regulations. There are several existing landslides in the Heavenly Valley Creek watershed, and the watershed is also avalanche- prone.

Vegetation within the watershed includes coniferous forest, sagebrush and other shrub associations, and some Stream Environment Zone (riparian and meadow) vegetation. Trees are sparse and stunted about 9000 feet. The Lake Tahoe region provides habitat for over 250 resident or migratory vertebrate species including 64 species of mammals, 168 species of birds, and 24 species of reptiles and amphibians. Site surveys for sensitive wildlife species were conducted during preparation of the Heavenly Master Plan. The surveys confirmed the presence of pine marten, Sierra Nevada snowshoe hare, northern goshawk, golden eagle, mountain quail, and Cooper’s hawk in the Master Plan project area. Heavenly Valley Creek is considered "marginal" fish habitat. Although several individuals of the federally threatened Lahontan cutthroat trout were found in the creek during surveys in 1990, the creek is not included in the U.S. Fish and Wildlife Service recovery plan for that species.

Section 21092.6 of CEQA requires lead agencies to disclose whether project sites are on the list of hazardous substance sites which is required to be maintained under Government Code 65962.6. Regional Board staff consulted with staff of several local government planning and environmental health departments who were unaware of the existence of the list, indicating that the Heavenly Valley Creek watershed does not contain any listed sites.

As of 1995, the Heavenly Valley Creek watershed included 221 acres of ski runs and roads. Potential new development in the Heavenly Valley Creek watershed under the Master Plan includes four new ski lifts, a “Top Station” for the new resort gondola (most gondola facilities are in another watershed), four new ski runs, 3600 feet of new road, a reconstructed ski lodge, and a relocated maintenance building. Parts of two ski runs and the relocated maintenance building are within the Nevada portion of the watershed.

The following socioeconomic information is taken from the Environmental Impact Report/Statement for the Heavenly Ski Resort Master Plan (Tahoe Regional Planning Agency, 1995). The 1990 census population of the California-Nevada urbanized area in the southern Lake Tahoe Basin was 35,767. About 60 percent of these people lived in the City of South Lake Tahoe. The economy of the Lake Tahoe Basin is dominated by tourism, and service employment related to tourism. In 1990, the labor force of the Heavenly Master Plan study area was 21,304 people, and the unemployment rate was 6.1%. The Heavenly ski resort attracts an average of 700,000 skier visits per year and about 68,000 summer visits. Heavenly has between 200 and 1300 full time equivalent employees; employment varies seasonally. Under the 1996 Master Plan, Heavenly is expected to attract 297,000 new skier visits per year, to provide more than $25 million in new spending for the local economy, and to hire 1,011 new employees by the time of buildout (after 20 years).

ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS

Environmental Impacts. The environmental checklist below supports the conclusion that the proposed Basin Plan amendments will not directly or indirectly have any new significant adverse environmental effects (defined as physical changes in the environment by State CEQA Guidelines Section 15382). The physical environmental impacts of the watershed restoration projects referenced in the TMDL load allocation analysis (California Regional Water Quality Control Board, Lahontan Region, 2000) have already been analyzed and mitigated in the environmental document for the Heavenly Master Plan (TRPA, 1995, 1996). Separate environmental review and mitigation (under CEQA and/or the National Environmental Policy Act) will be required for new ski resort development projects as they are proposed. The additional monitoring requirements included in the TMDL implementation program may indirectly lead to local, short term physical changes in the environment (e.g., collection of stream invertebrates for identification); however these changes will not be significant. There will also be no physical changes in the environment as a result of adopting the new introductory language for Basin Plan Section 4.13. Therefore, this environmental document can be considered the functional equivalent of a Negative Declaration. No discussion of alternatives is necessary. No new mitigation is required.

Socioeconomic Impacts. The proposed Basin Plan amendments will increase demands on Regional Board staff time to evaluate the progress of TMDL implementation, determine future needs for revisions in the TMDL and implementation program, and prepare a revised TMDL if necessary (Checklist Question IXe). Public Resources Code Sections 21159 and 21159.4 require Regional Boards, when adopting requirements for the installation of new pollution control equipment, or new performance standards for pollution control, to analyze reasonable means of compliance with the new regulations. The proposed TMDL and implementation program are "new performance standards" designed to ensure the attainment of existing water quality standards. The implementation program relies substantially on existing watershed restoration and monitoring programs which are being carried out by the U.S. Forest Service and funded by the Heavenly ski resort. The proposed TMDL implementation plan includes recommendations for additional monitoring (bioassessment of benthic invertebrates and their habitat) which may increase overall monitoring costs. The Regional Board's current biomonitoring protocol involves costs of about $2500/station/year including evaluation of physical habitat factors, or $1500/station/year for sampling and identification of invertebrates alone (Thomas Suk, personal communication). A minimum of three sampling stations each are recommended for Heavenly Valley Creek and Hidden Valley Creek, with two years of sampling to determine baseline conditions and sampling every two years thereafter This could result in additional costs of about $9000-$15,000 per year during years in which sampling is done. However, it may be possible to offset at least part of these costs through modifications to the existing monitoring program. The final sampling program will be determined through consultation among Regional Board staff , LTBMU staff, and Heavenly ski resort staff.

ENVIRONMENTAL CHECKLIST

	YES	*MAYBE*	*NO*
I. LAND USE AND PLANNING- *Would the proposal:*			
a. Conflict with general Plan designation or zoning?			x
b. Conflict with applicable environmental plans or policies adopted by agencies with jurisdiction over the project?			x
c. Be incompatible with existing land use in the vicinity?			x
d. Affect agricultural resources or operations (e.g., impact to soils or farmlands, or impacts from incompatible land uses?			x
e. Disrupt or divide the physical arrangement of an established community (including a low-income or minority community)?			x
II. POPULATION AND HOUSING- *Would the proposal:*			
a. Cumulatively exceed official regional or local population projections?			x
b. Induce substantial growth in an area either directly or indirectly (e.g., through projects in an undeveloped area or extension of major infrastructure?			x
c. Displace existing housing, especially affordable housing?			x
III. GEOLOGIC PROBLEMS: *Would the proposal result in or expose people to potential impacts involving:*			
a. Fault rupture?			x
b. Seismic ground shaking?			x
c. Seismic ground failure, including liquefaction?			x
d Seiche, tsunami, or volcanic hazard?			x
e. Landslides or mudflows?			x
f. Erosion, changes in topography or unstable soil conditions from excavation, grading, or fill?			x
g. Subsidence of land?			x
h. Expansive soils?			x
i. Unique geologic or physical features?			x
IV. WATER- *Would the proposal result in:*			
a. Change in absorption rates, drainage patterns, or the rate and amount of surface runoff?			x
b. Exposure of people or property to water related hazards such as flooding?			x
c. Discharge into surface waters or other alteration of surface water quality (e.g., temperature, dissolved oxygen or turbidity?			x

	YES	*MAYBE*	*NO*
d. Changes in the amount of surface water in any water body?			x
e. Changes in currents, or the course or direction of water movements?			x
f. Change in the quantity of ground waters, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations or through substantial loss of groundwater recharge capability?			x
g. Altered direction or rate of flow of groundwater?			x
h. Impacts to groundwater quality?			x
i. Substantial reduction in the amount of groundwater otherwise available for public water supplies?			x
V. AIR QUALITY- *Would the proposal* a. Violate any air quality standard or contribute to an existing or protected air quality violation?			
b. Expose sensitive receptors to pollutants?			x
c. Alter air movement, moisture, or temperature, or cause any change in climate?			x
d. Create objectionable odors?			x
VI. TRANSPORTATION/CIRCULATION: *Would the proposal result in:*			
a. Increased vehicle trips or traffic congestion?			x
b. Hazards to safety from design features (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?			x
c. Inadequate emergency access or access to nearby uses?			x
d. Insufficient parking capacity onsite or offsite?			x
e. Hazards or barriers for pedestrians or bicyclists?			x
f. Conflicts with adopted policies supporting alternative transportation (e.g., bus turnouts, bicycle racks)?			x
g. Rail, waterborne, or air traffic impacts?			x
VII. BIOLOGICAL RESOURCES- *Would the proposal result in impacts to:*			
a. Endangered, threatened or rare species or their habitats (including but not limited to plants, fish, insects, animals, and birds?			x
b. Locally designated species (e.g., heritage trees)?			x
c. Locally designated natural communities (e.g., oak forest, coastal habitat, etc.)?			x

	YES	*MAYBE*	*NO*
d. Wetland habitat (e.g., marsh, riparian and vernal pool)?			x
e. Wildlife dispersal or migration corridors?			x
VIII. ENERGY AND MINERAL RESOURCES- *Would the proposal*:			
a. Conflict with adopted energy conservation plans?			x
b. Use nonrenewable resources in a wasteful and inefficient manner?			x
c. Result in the loss of availability of a known mineral resource that would be of future value to the region and the residents of the State?			x
IX. HAZARDS- *Would the proposal involve*:			
a. A risk of accidental explosion or release of hazardous substances (including, but not limited to, oil, pesticides, chemicals, or radiation)?			x
b. Possible interference with an emergency response plan or emergency evacuation plan?			x
c. The creation of any health hazard or potential health hazard?			x
d. Exposure of people to existing sources of potential health hazards?			x
e. Increased fire hazard in areas with flammable brush, grass, or trees?			x
X. NOISE- *Would the proposal result in:*			
a. Increases in existing noise levels?			x
b. Exposure of people to severe noise levels?			x
XI. PUBLIC SERVICES- *Would the proposal have an effect upon, or result in a need for new or altered government services in any of the following areas:*			
a. Fire protection?			x
b. Police protection?			x
c. Schools?			x
d. Maintenance of public facilities, including roads?			x
e. Other government services?	x		
XII. UTILITIES AND SERVICE SYSTEMS. *Would the proposal result in a need for new systems or supplies, or substantial alterations to the following utilities:*			
a. Power or natural gas?			x
b. Communications systems?			x
c. Local or regional water treatment or distribution facilities?			x
d. Sewer or septic tanks?			x
e. Storm water drainage?			x

	YES	*MAYBE*	*NO*
f. Solid waste disposal?			x
g. Local or regional water supplies?			x
XIII. AESTHETICS- *Would the proposal:*			
a. Affect a scenic vista or scenic highway?			x
b. Have a demonstrable negative aesthetic effect?			x
c. Create light or glare?			x
XIV. CULTURAL RESOURCES- *Would the proposal:*			
a. Disturb paleontological resources?			x
b. Disturb archaeological resources?			x
c. Have the potential to cause a physical change which would affect unique ethnic cultural values?			x
d. Restrict existing religious or sacred uses within the potential impact area?			x
XV. RECREATION- *Would the proposal*:			
a. Increase the demand for neighborhood or regional parks or other recreational facilities?			x
b. Affect existing recreational opportunities?			x
XVI. MANDATORY FINDINGS OF SIGNIFICANCE:			
a. Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?			x
b. Does the project have the potential to achieve short-term, to the disadvantage of long-term, environmental goals?			x
c. Does the project have impacts that are individually limited, but cumulatively considerable? (Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.)			x
d. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?			x

Determination:

On the basis of this initial evaluation:

I find that the proposed Basin Plan amendment COULD NOT have a significant effect on the environment. ___X____

I find that, although the proposed Basin Plan Amendment COULD have a significant effect on the environment, there WILL NOT BE a significant effect in this case because the mitigation measures described on an attached sheet have been incorporated into the proposed Basin Plan amendment. _______

I find that the proposed Basin Plan amendment COULD have a significant effect on the environment. _______

____________________________________ ____________________

Robert S. Dodds, Assistant Executive Officer Date

LIST OF PREPARERS

The Basin Plan amendment language, CEQA document and technical staff report were drafted by Judith Unsicker, Environmental Specialist IV (Specialist) at the Lahontan Regional Board's South Lake Tahoe Office, and reviewed by Robert S. Dodds, Assistant Executive Officer. Stefan Lorenzato of the Division of Water Quality, SWRCB, performed the calculations used in the TMDL source analysis and load allocations, and helped to determine the overall scope of the TMDL.

LIST OF PERSONS CONSULTED

We thank Dr. G. Mathias Kondolf of the University of California, Berkeley, for scientific peer review of earlier drafts of the TMDLs, CEQA document and technical staff report. Substantial changes in the TMDLs were made as a result of Dr. Kondolf's comments. Changes were also made in response to comments by and discussions with USEPA staff and consultants (Joe Karkoski, Jane Freeman, Neil Berg, Janet Whitlock, David Smith, Janet Parrish) and SWRCB staff (Steven Blum, Sheila Vassey, John Mattox, Stefan Lorenzato, and Greg Frantz). Thomas Suk of Regional Board staff provided information about the biomonitoring protocol. Thanks are also due to Sherry Hazelhurst and Andrea Holland of the U.S. Forest Service, and Andrew Strain of Heavenly ski resort staff for help which included providing information, answering questions, and organizing a watershed tour.

Regional Board staff contacted El Dorado County Environmental Health Department staff, including John Morgan and Ginger Huber, and staff of the City of South Lake Tahoe and El Dorado County Planning Departments regarding the hazardous substance sites list required by Government Code Section 65962.5.

LITERATURE CITED

(Citation of the following documents is not meant to imply incorporation by reference.)

California Regional Water Quality Control Board, Lahontan Region, 1995. *Water Quality Control Plan for the Lahontan Region* (as amended).

California Regional Water Quality Control Board, Lahontan Region, 1998. Notice of Preparation of a Draft Environmental Document for Proposed Amendments to the Lahontan Basin (Basin Plan), and Initial Study. State Clearinghouse Number 98092502.

California Regional Water Quality Control Board, 2000. *Technical Staff Report: Total Maximum Daily Loads for Sediment and Implementation Plan, Heavenly Valley Creek, El Dorado County, California.* November 2000

Tahoe Regional Planning Agency and U.S. Forest Service, Lake Tahoe Basin Management Unit, 1995-96. *Draft and Final Environmental Impact Report/Statement, Heavenly Ski Resort Master Plan.* 5 Volumes. Prepared by Harland Bartholomew & Associates and subcontractors. (Draft dated April 1995; Final dated June 1996).

TECHNICAL STAFF REPORT:

TOTAL MAXIMUM DAILY LOAD FOR SEDIMENT AND IMPLEMENTATION PLAN, HEAVENLY VALLEY CREEK, EL DORADO COUNTY, CALIFORNIA

California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Boulevard
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(530) 542-5400

November 2000

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Section 1. Executive Summary

Heavenly Valley Creek is located in a small, high elevation forested watershed in the southeastern part of the Lake Tahoe Basin, in El Dorado County, California and Douglas County, Nevada. Since 1956, the upper Heavenly Valley Creek watershed has been disturbed by construction and maintenance activities at the Heavenly Valley (later renamed "Heavenly") ski resort. During the 1989-1990 listing cycle, Heavenly Valley Creek was placed on the list of impaired surface water bodies which require development of Total Maximum Daily Loads (TMDLs) pursuant to Section 303(d) of the federal Clean Water Act. Implementation plans are also required for TMDLs. Heavenly Valley Creek was listed due to impairment from sediment based on the historic information summarized in Section 3.1 below.

TMDLs are strategies to ensure the attainment of water quality standards. By definition, the "Total Maximum Daily Load" of a pollutant which can be allowed if standards are to be attained is equivalent to the sum of "wasteload allocations" for point sources of pollutants, "load allocations" for nonpoint sources, and an explicit or implicit margin of safety to allow for uncertainty in the analysis.

The California Regional Water Quality Control Board, Lahontan Region (Regional Board) has developed a TMDL for sediment in Heavenly Valley Creek which, when implemented, is expected to result in the attainment of applicable water quality objectives and the protection of beneficial uses. The beneficial uses of concern are those associated with aquatic habitat. The Regional Board is also considering adoption of a TMDL implementation program based substantially on completion of ongoing watershed restoration activities at the ski resort, and continuation of a comprehensive U.S. Forest Service monitoring program. (The watershed area affected by the TMDL is entirely within the boundaries of the Heavenly ski resort, on National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit.)

The TMDL and implementation program will be considered for adoption as amendments to the Regional Board's *Water Quality Control Plan for the Lahontan Region* (Basin Plan). This staff report summarizes the technical background for the proposed amendments. More detailed information is contained in supplementary reports which will be included in the administrative record of the Basin Plan amendment process.

Components of the TMDL

The TMDL includes:

- A problem statement
- Numeric targets
- Source analysis
- Linkage analysis
- Load allocations, and

- Discussion of the margin of safety and seasonal and annual variation.

The TMDL implementation program includes:

- A description of the remedial actions to be performed
- A monitoring program related to the numeric targets, and
- A schedule for review and revision of the TMDL.

Problem Statement. The TMDL focuses on the listed segment of Heavenly Valley Creek from the headwaters downstream to the resort permit boundaries. The problem statement includes assessment of existing instream and watershed conditions in relation to water quality standards and conditions in a nearby reference stream. Monitored suspended sediment concentrations have been higher than those at reference stations since the 1970s, and at times have exceeded a regional numerical suspended sediment standard. Sedimentation contributed to the degradation of benthic invertebrate communities in Heavenly Valley Creek as early as 1972, and to ranking of the stream as "marginal" fish habitat by 1982. By 1995, sediment delivery from the watershed was estimated to be about 14.5 times estimated sediment delivery under natural conditions.

Numeric Targets. The numeric targets interpret water quality standards (including narrative sediment objectives related to beneficial use support) and provide indicators of watershed health. They are an expression of desired future conditions associated with a stable watershed and a stream capable of supporting healthy aquatic habitat. The indicators and targets are identified in Tables 5 and 8. Attainment of numeric targets, will be evaluated in relation to conditions in a nearby reference stream and its watershed.

Source Analysis. The source analysis uses outputs from a model developed by the U.S. Forest Service to estimate sediment delivery to Heavenly Valley Creek from unpaved roads, ski runs, and undisturbed areas within the watershed, and calculations based on suspended sediment data collected in Heavenly Valley Creek between 1996 and 1999. The modeled "total impaired" sediment load (assuming no use of Best Management Practices or BMPs) is 150 tons/year (including both suspended and bedload sediment). The modeled load for1996-99, which reflects some improvement due to BMPs already implemented, is 116 tons per year. The estimated average annual historic total (suspended plus bedload) sediment loading for Hidden Valley Creek between 1991 and 1999 is 45 tons. Factors contributing to increased sediment delivery as a result of watershed disturbance include: highly erodible decomposed granite soils, steep slopes prone to avalanches and mass wasting, short growing season which makes revegetation difficult, and past ski resort maintenance practices which led to repeated disturbance. The total instream load for Heavenly Valley Creek is divided among hillslope source categories as follows: 62 % from roads, 32% from ski runs, and 6 % from undisturbed lands.

Linkage Analysis. The linkage analysis discusses the relationship between hillslope sediment production processes and effects on instream water quality and beneficial uses. It provides the basis for estimating the magnitude of sediment loading reductions, and the hillslope controls, necessary to attain water quality objectives and protect beneficial uses.

An inferred linkage is used, with the assumption that the numeric target will adequately protect beneficial uses and therefore ensure compliance with narrative objectives because it is reasonably close to the estimated sediment load in Hidden Valley Creek. A literature review also indicates that attainment of the target should provide adequate habitat conditions for adult fish and that the creek's steep gradient and high degree of winter scour would not provide good spawning habitat even under natural sediment loading conditions. There is historic evidence that Heavenly Valley Creek was already degraded before the first applicable water quality standards were adopted, and reduction of sediment loading to "pristine" conditions may not be necessary to provide the required level of beneficial use protection. The instream loading capacity is set at 53 tons per year, as a 5 year rolling average, which (considering differences in watershed size) is considered reasonably close to the estimated 45 tons per year load in the reference stream, and which represents a 65% reduction in estimated historic loading. This substantial reduction is expected to expected to allow recovery of stream channel and riparian conditions over time and thus recovery of aquatic invertebrate communities and protection of adult fish populations.

Load Allocations. There are no point sources of sediment in the affected watershed. Therefore, the "wasteload allocation" for this TMDL is zero. Load allocations for instream total sediment are set for source categories (roads, ski runs, undeveloped lands, and proposed new development) in proportion to modeled hillslope sediment delivery reductions from each source after full application of Best Management Practices. Load allocations are summarized in Table 13.

Margin of Safety and Seasonal and Annual Variation. There is inherent seasonal and annual variation in sediment delivery to streams, and in the impacts of sediment on aquatic species during different critical life stages. The Heavenly Valley Creek TMDL addresses long term erosion patterns and instream impacts by using longer time frames for implementation and evaluation, and relies on an adaptive management approach. Load allocations are expressed as 5 year rolling averages to account for seasonal and annual variability. The TMDL and allocations are expected to promote recovery of aquatic habitat over time to the point which will support the beneficial uses of concern. The TMDL contains an implicit margin of safety, based on conservative assumptions, to compensate for uncertainty in the analysis, and to ensure that the allocations, when achieved, will result in attainment of standards.

Public Participation. Public participation for the TMDL will be provided through the Regional Board's Basin Plan amendment process (which includes public review under the California Environmental Quality Act, and adoption following a noticed public hearing), and through subsequent public review periods preceding approvals of the Basin Plan amendments by the California State Water Resources Control Board (State Board) and the U.S. Environmental Protection Agency (USEPA). The State Board will submit the Basin Plan amendments, with supporting documentation, to the USEPA for approval as TMDLs after they have been approved by the California Office of Administrative Law.

Implementation and Monitoring Programs. Because the entire subwatershed affected by the Heavenly Valley Creek TMDL is within USFS ownership, the responsibility for implementation rests with the USFS and its permittee, the Heavenly ski resort. The implementation program involves completion of a U.S. Forest Service- mandated watershed restoration program (funded by the resort) which calls for application of Best Management Practices for erosion control to all historically disturbed areas, and to all future development, in the subwatershed affected by the TMDL. The restoration program began in 1997 and is expected to be completed in 2006. It is an adaptive management program, involving annual evaluation of BMP effectiveness and refinement of management practices as appropriate.

Projected implementation of the TMDL also involves continuation of the existing U.S. Forest Service monitoring program (funded by the ski resort), which already addresses most of the instream and hillslope indicators. Bioassessment of benthic invertebrate communities, using a protocol which also assesses a variety of other instream and riparian conditions, will be added to the monitoring program.

The TMDL implementation plan for Heavenly Valley Creek is noncontroversial and there is a good probability of continued implementation. Formal commitments to the existing watershed restoration and monitoring programs have already been made by stakeholders including the Heavenly ski resort, the U.S. Forest Service, and the Tahoe Regional Planning Agency.

The Regional Board has authority under the Clean Water Act and the California Water Code to ensure implementation of the Heavenly Valley Creek TMDL in California. Initially, the Board will rely on the three-tier implementation approach outlined in the statewide *Plan for California's Nonpoint Source Pollution Control Program* (California State Water Resources Control Board, 2000). Authority to ensure implementation in Nevada includes the U.S. Forest Service's permitting authority over the Heavenly ski resort, and the bistate Tahoe Regional Planning Agency's charge under P.L. 96-551 to ensure attainment of the most stringent state and federal water quality standards. Attainment of water quality standards is projected to occur within 20 years of final approval of the TMDL (in 2021).

Review and Revision of the TMDL. Regional Board staff will review the annual monitoring reports produced by the U. S. Forest Service and will participate in the adaptive management approach to erosion control through the interagency technical advisory group. Progress toward attainment of the load allocations and of water quality standards will be reviewed at five year intervals, to coincide with the U.S. Forest Service's planned comprehensive reviews of monitoring data and the success of the erosion control program. (The first such review is being done in 2000.) If satisfactory progress is not being made, revision of the TMDL will be considered.

Section 2. Introduction

The Lahontan Regional Water Quality Control Board (Regional Board) is the California State agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Regional Boards which function as part of the State Water Resources Control Board (State Board) system within the California Environmental Protection Agency. The Lahontan Regional Board implements both the federal Clean Water Act and the Porter-Cologne Water Quality Control Act, which is part of the California Water Code. Water quality standards and control measures for waters of the Lahontan Region are contained in the Regional Board's *Water Quality Control Plan for the Lahontan Region* (Basin Plan).

Under Section 303(d) of the Clean Water Act, the Regional Board must identify surface waters which are not meeting water quality standards and are not expected to do so even with the use of technology-based controls. For Section 303(d)-listed waters, the Regional Board must develop strategies called "Total Maximum Daily Loads" or TMDLs. TMDLs involve calculation of pollutant loads from all point and nonpoint sources in the watershed, and determination of the reductions in pollutant loads from each of these sources, which, when considered together with a "margin of safety," are necessary for attainment of standards. TMDL implementation programs are required under 40CFR 230.6 and the California Water Code, and California TMDLs and their associated implementation programs must be adopted as Basin Plan amendments.

Heavenly Valley Creek is a tributary of Trout Creek in the southeast portion of the Lake Tahoe watershed. The segment of Heavenly Valley Creek within the boundaries of the Heavenly Ski Resort (a U.S. Forest Service permittee) is Section 303(d)-listed for sedimentation problems related to watershed disturbance for ski resort development and maintenance. Sedimentation of Heavenly Valley Creek is of concern not only because of its impact on instream beneficial uses, but also because of its cumulative contribution to the degradation of Lake Tahoe through addition of sediment and sediment-bound nutrients. (Lake Tahoe is on the Section 303(d) list for significant loss of transparency and increased phytoplankton productivity, in violation of water quality standards.)

The Lahontan Regional Board proposes to amend its Basin Plan to incorporate a TMDL and an Implementation Plan to address sedimentation problems related to ski resort development in the upper watershed of Heavenly Valley Creek. The TMDL is based on past modeling of sediment loads and feasible loading reductions by the U.S. Forest Service, Lake Tahoe Basin Management Unit (USFS), on monitoring data, and other readily available information. The proposed Basin Plan amendment language for Heavenly Valley Creek includes the basic information required in TMDLs under federal regulations (40 CFR 130.2), summaries of the implementation and monitoring programs, and a schedule for review and revision of the TMDL. This staff report summarizes the technical background for the Heavenly Valley Creek TMDL and implementation program. The report is organized in a format similar to that used for TMDLs adopted directly for California waters by the USEPA, Region IX. However, it is <u>not</u> in itself the TMDL proposed for state adoption.

Section 3. Supporting Information for TMDL Components

The TMDL is based primarily on modeling data and other information in the draft and final Environmental Impact Statements (EISs) for the Heavenly Ski Resort Master Plan (Tahoe Regional Planning Agency, 1995 and 1996), on hillslope and instream monitoring data from USFS monitoring reports (Hazelhurst and Widegren, 1998 and Hazelhurst *et al*., 1999), and on unpublished USFS monitoring data (Sherry Hazelhurst, personal communication). Relevant excerpts from these reports, and from other reports cited in the "References" section, will be made part of the administrative record of the Basin Plan amendments. A detailed summary of the USFS model used as the basis for the TMDL source analysis and load allocations is included as Appendix 1 to this staff report. The administrative record will also include a separate environmental document prepared pursuant to the California Environmental Quality Act (CEQA) to address environmental and socioeconomic impacts of the proposed Basin Plan amendments.

The USEPA's (1999) protocol for developing sediment TMDLs states that projects which focus on implementation planning (and for which TMDLs are a by-product) can often use less complex methods of developing TMDLs because specific implementation actions can be identified, agreed to, and implemented without controversy. The protocol also states that less complex TMDLs are appropriate for small watersheds. Heavenly Valley Creek is located in a small (1341 acres) subwatershed where stakeholders have agreed upon and are already implementing a comprehensive sediment control program under an adaptive management approach. The TMDL can be considered a "by-product" of the development and implementation of the erosion control and monitoring programs in the 1996 Heavenly Ski Resort Master Plan. The Heavenly Valley Creek sediment TMDL uses a relatively simple sediment delivery model as the basis for the source analysis and load allocations, includes an implicit margin of safety, and relies on monitoring of multiple numeric indicators to demonstrate attainment of narrative water quality objectives over time. Regional Board staff believe that the implementation and monitoring programs support this "less complex" approach.

Section 3.1. Problem Statement

There is evidence from a variety of sources that, in comparison with other streams in the Lake Tahoe Basin with similar geology and less watershed disturbance, the water quality and beneficial uses of Heavenly Valley Creek have been significantly affected by increased sediment delivery from ski resort development. Documented instream problems include elevated suspended sediment concentrations and loading, degraded stream channel conditions, degraded benthic invertebrate communities and "marginal" fish habitat conditions (TRPA, 1996). Documented hillslope problems include modeled increases in sediment delivery to the stream from unpaved roads and ski runs, compared to modeled natural sediment yield from the watershed. Heavenly Valley Creek was classified as "impaired", and subsequently placed on the Section 303(d) list, during the Lahontan Regional Board's 1989-1990 water quality assessment cycle. Listing reflected the significance of sedimentation from historic disturbance throughout the upper watershed, and two significant mass wasting incidents in the 1980s.

The following is a more detailed summary of historic and existing sediment problems in relation to applicable water quality standards. Additional information on historic and existing conditions is provided in the discussion of numeric targets and indicators.

A. Watershed Overview

Geographic scope of TMDLs. Heavenly Valley Creek is a tributary of Trout Creek, which in turn is tributary to the Upper Truckee River and then to Lake Tahoe (Figure 1). The listed segment of Heavenly Valley Creek extends from the headwaters to the permit boundaries of the Heavenly ski resort (Figure 2). Its watershed is entirely within National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit (USFS/LTBMU). The LTBMU legally includes portions of the Tahoe, El Dorado, and Humboldt-Toiyabe National Forests, but is a separate administrative unit with its own Forest Supervisor and Land and Resource Management Plan (USFS, 1988). The LTBMU's plan has water quality protection as its primary goal.

Throughout this staff report, references to the "Heavenly Valley Creek watershed" and "Heavenly Valley Creek" refer to the subwatershed and Section 303(d) listed creek segment within the LTBMU and the ski resort permit boundaries. Heavenly Valley Creek flows for about a mile outside of the LTBMU boundary through private lands before joining Trout Creek. This lower segment has been affected by past wastewater disposal to land and by urban development. Insufficient monitoring data were available at the time the upper segment was listed to determine whether the lower segment should be included. The Tahoe Regional Planning Agency (1998) has since proposed a fish habitat restoration project for this segment. A TMDL for the lower segment, if needed, will be addressed as part of the future development of TMDLs for Lake Tahoe.

The TMDL analysis uses another tributary of Trout Creek as a reference stream. This stream has an undisturbed watershed, with streamflow, geology, and vegetation similar to those of Heavenly Valley Creek. Its watershed area is about 87 % of that of Heavenly Valley Creek (1162 acres vs. 1341 acres). The reference stream has no official geographic name but is called "Hidden Valley Creek" by USFS staff. Its location is shown in Figure 1.

The USFS model used in development of the TMDL source analysis and load allocations does not distinguish between sources in California and Nevada. The Nevada portion of the watershed (57 of 1341 acres) has no mapped surface waters. The TMDL addresses suspended sediment loads from the entire watershed. As noted in the discussion of the implementation program below, the USFS and the Tahoe Regional Planning Agency have already made formal commitments to the remedial erosion control and monitoring programs which are important components of the TMDL implementation plan, and these agencies have authority to ensure implementation in Nevada.

Geology, Soils, and Natural Hazards. Soils within the Heavenly Valley Creek watershed are highly erodible, excessively well drained, and contribute to high peak discharges during rainstorms or spring runoff. They are derived from granitic parent material, in all stages of decomposition. A number of the soils at the Heavenly resort have more rapid runoff once disturbed and bare, while runoff under natural conditions is usually moderate. Once disturbed, these soils are difficult to revegetate because of low fertility, low water holding capacity, and harsh climatic conditions (Etra, 1984). Under the Bailey land capability system used in land use and water quality planning and permitting in the Lake Tahoe Basin (see Section 5.4 of the Lahontan Basin Plan), most of the lands within the Heavenly Valley Creek watershed are capability Class 1 or 2 and would currently be allowed only 1 percent impervious surface coverage or permanent soil disturbance. In 1995, there were about 221 acres of roads and ski runs in the watershed (about 16.5% disturbance). Most of this watershed disturbance occurred before limits were placed on impervious surface coverage in the Lake Tahoe Basin. Disturbance after 1980 was mitigated under the requirements of the Regional Board and/or TRPA water quality plans.

The resort has steep to very steep slopes (30-70 percent), and sediment has the potential to reach Lake Tahoe rapidly because the Sky Meadow Reservoir in the Heavenly Valley Creek drainage provides the only significant opportunity to trap sediment. Following severe watershed damage from an August 1983 rainstorm, the reservoir filled almost to capacity (22-28 acre-feet) with sediment. Sediment was later removed from the reservoir to fill upgradient rills and gullies. There is no similar containment downstream of the reservoir. There are several existing landslides in the Heavenly Valley Creek watershed; the watershed is also avalanche- prone and includes four avalanche control areas.

Climate and Hydrology**.** The Lake Tahoe Basin’s climate includes cold wet winters and temperate, mostly dry summers. Precipitation comes from both winter Pacific storms and summer thundershowers; it falls as snow from October to April and as rain from May to September. Snow depths generally reach 8 to 12 feet in the mountains surrounding Lake Tahoe, usually in February or March. There are large seasonal and diurnal variations in temperature, and a short growing season (about 70 to 120 frost free days). The mean annual precipitation is 30 inches per year.

Heavenly Valley Creek originates from springs and seeps. Four first order channels merge to form two second order channels, which then merge as a third order creek. The main channel extends from Sky Canyon at 9,300 feet to the confluence with Trout Creek at 6,255 feet (Hazelhurst and Widegren, 1998). The stream slope ranges from 2.7 percent to 36 percent, with an average of 20.2 percent. The drainage density is 1.32 miles per square mile. The usual seasonal pattern involves low winter base flows and peak runoff period in May or June. (During drought years, peak snowmelt flow has been observed as early as March.) Summer flows are generally lower. The maximum recorded flow was 28 cfs in June 1983. Heavenly Valley Creek is generally perennial, but there have sometimes been periods with no flow. (The period of record includes the severe drought of the 1980s and early 1990s.)

Heavenly Valley Creek as a whole is about 4.4 miles long, with about 2.7 miles within the resort boundary. The listed segment of the creek has a drainage area of 2.1 square miles (1,341 acres, including about 57 acres in Nevada). The creek's elevation change is 3,400 feet (from 9,080 feet to 6,255 feet at its confluence with Trout Creek), although the watershed includes Monument Peak (elevation 10,058 feet). The average stream gradient is about 20 percent. The Heavenly Valley Creek watershed is called "Watershed CA-1" in some of the USFS maps and tables of modeling data which will be included in the administrative record for the Basin Plan amendments. Watershed boundaries are shown in Figure 3.

Sky Meadows Reservoir, located in the upper part of the watershed (Figure 2) stores water for use in snowmaking. It receives both natural inflow from a drainage area of about 550 acres and water imported from California and Nevada sources outside of the Heavenly Valley Creek watershed. The net effects of added runoff from manmade snow and summer diversions for irrigation of revegetated areas on summer flows in the creek have not been determined. However, diversions are a factor in the rating of fish habitat quality in the creek as "marginal" (TRPA, 1996).

Terrestrial Biota. The watershed is forested, although trees are sparse and stunted above about 9000 feet. Dominant forest associations include Mixed Conifer-Fir, Lodgepole Pine, and Red Fir. There are also brush communities dominated by sagebrush, manzanita, ceanothus, and mountain mahogany, and some areas dominated by forbs such as mule's ears, or by perennial grass. Vegetative cover is not continuous; large areas of unvegetated soil may occur between stands of shrubs (Etra, 1984).

There are about 83 acres of Stream Environment Zone (SEZ), in the Heavenly Valley Creek watershed, about 14 acres of which have been affected by human activities. "Stream Environment Zone" is a Lake Tahoe Basin land use planning category which includes lakes, streams, wetlands, and riparian areas, but which involves delineation criteria separate from federal wetlands criteria. Because of their filtering capacity for sediment and nutrients, protection and restoration of SEZs is considered important for protection of water quality throughout the Lake Tahoe watershed.

Over 250 species of resident and migratory vertebrate wildlife are known to occur in the Lake Tahoe Basin. Stream Environment Zones are considered especially important wildlife habitat. Sensitive wildlife species observed at or near the Heavenly ski resort include California spotted owl, great gray owl, northern goshawk, pine marten, Sierra Nevada snowshoe hare, American badger, mountain quail, golden eagle, Cooper's hawk, and sharp-shinned hawk.

Fisheries and Aquatic Habitat. The degree to which the upper reaches of Heavenly Valley Creek historically supported game fish is unknown. The only trout native to the

Lake Tahoe Basin is the Lahontan cutthroat trout, now listed as "threatened" under the federal Endangered Species Act. Many of the high elevation lakes and streams of the Lahontan Region were "fishless" until game fish planting, often with exotic species, began in the 19th century. Fish habitat in Heavenly Valley Creek has been classified as "marginal" since a 1982 survey (TRPA, 1996). Samples of benthic invertebrates at seven stations in Heavenly Valley Creek between 1972 and 1974 showed 151-7420 individuals per square meter, classified in 5-27 genera (Baker and Davis, 1976). See the discussion of sediment impacts on beneficial uses below for more information on aquatic habitat issues.

Land Use. The Lake Tahoe watershed as a whole was severely disturbed by 19th century logging and grazing. The extent of specific disturbance in the Heavenly Valley Creek and Hidden Valley Creek watersheds is unknown, but given its present high quality, Hidden Valley Creek may be assumed to have recovered from the disturbance. Development of ski resort facilities in the Heavenly Valley Creek watershed began in 1956. As of 1995, the 1341 acre watershed included 221 acres of ski runs and roads. Hydromodification of the creek has included construction of the snowmaking reservoir and associated pipelines, and placement of 200 yards of the creek into a culvert. Past construction practices involved preparing new ski runs by bulldozing all vegetation and removing the thin topsoil layer. Maintenance practices, called "summer grooming" involved repeated mechanical removal of rocks and vegetation from ski runs in order to allow skiing when snow was not deep. The current practice for construction of new ski runs involves cutting trees but leaving natural rocks, vegetation, and duff, and using snowmaking to maintain an obstacle-free cover for skiing. The USFS and U.S. Natural Resource Conservation Service have implemented a variety of erosion control and revegetation projects within the Heavenly resort boundaries since 1965, with varying degrees of success. However, the erosion control program which forms the basis of the current TMDL implementation program is the result of a comprehensive effort to document and meet restoration needs throughout the Heavenly Valley Creek watershed.

Projected new development in the watershed under the 1996 Master Plan includes four new ski lifts, a “Top Station” for the new resort gondola (most gondola facilities are in another watershed), four new ski runs, expansion of the snowmaking system, 3600 feet of new road, a reconstructed ski lodge, and a relocated maintenance building. Some of this construction has already occurred (USFS, 1998). Parts of two ski runs and the relocated maintenance building are within the Nevada portion of the watershed. New development is included in the TMDL load allocations below.

B. Applicable Water Quality Standards

Water quality standards in California include designated beneficial uses of water, and narrative and numerical water quality objectives (equivalent to federal “criteria”) set to protect those uses. The designated beneficial uses of Heavenly Valley Creek and its tributaries are Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Groundwater Recharge (GWR), Water Contact Recreation (REC-1), Non-Contact Water Recreation (REC-2), Commercial and Sportfishing (COMM), Cold Freshwater Habitat

(COLD), Wildlife Habitat (WILD), Rare and Endangered Species Habitat (RARE), Migration of Aquatic Organisms (MIGR), and Spawning of Aquatic Organisms (SPWN). Chapter 2 and Section 5.1 of the Basin Plan include definitions of each of these uses. With the exception of the RARE use, Hidden Valley Creek has the same designated beneficial uses as Heavenly Valley Creek. These are the uses of Trout Creek which apply upstream under the "tributary rule". (The Basin Plan states [page 3-13] that: "Where objectives are not specifically designated, downstream objectives apply to upstream tributaries.")

Not all of Heavenly Valley Creek's uses (e.g., MUN) are currently existing uses within the boundaries of the Heavenly ski resort. The RARE use was added in the 1995 Basin Plan update as a result of the presence of a small population of the threatened Lahontan cutthroat trout in 1990; however, the U.S. Fish and Wildlife Service has since determined that the creek does not constitute critical habitat for the trout (Sherry Hazelhurst, personal communication). Hikers are allowed recreational access to the watershed during the summer, but summer recreational (REC-1 and REC-2) use of the creek within the resort boundaries is probably relatively low compared to that of more easily accessible Lake Tahoe Basin streams. Winter recreational use of the watershed does not depend on the water quality or instream uses of the creek. The most important beneficial uses for purposes of interpreting the narrative sediment objectives are summarized in Table 1. Note that most of these uses are defined to encompass all types of aquatic organisms, not only fish.

Water quality objectives for Heavenly Valley Creek are set forth in Chapter 3 and Section 5.1 of the Lahontan Basin Plan. They include regionwide narrative objectives, narrative objectives for waters of the Lake Tahoe Basin, and numerical objectives which apply upstream from Trout Creek under the "tributary rule" cited above. No "site-specific" numeric objectives have been established for Heavenly Valley Creek *per se*.

The State water quality objectives of greatest importance for the proposed sediment TMDLs are the non-degradation objective, and three narrative objectives related to suspended and bedload sediment. The sediment objectives are cited in Table 2.
The nondegradation objective references State Water Resources Control Board Resolution 68-16 (which is included in the appendices to the 1995 Basin Plan). This resolution allows lowering of water quality in high quality waters only if specific findings can be made. No findings have ever been made by the State or Lahontan Regional Board to allow degradation of Heavenly Valley Creek in exchange for socioeconomic benefits. Lake Tahoe is a designated "Outstanding National Resource Water" under federal antidegradation regulations. No degradation of such waters can be allowed even where significant socioeconomic benefits would result.

The Lahontan Basin Plan (Section 5.2) also contains several waste discharge prohibitions applicable to sediment discharges in the Lake Tahoe Basin. There are general prohibitions against discharge of any waste or deleterious materials, including waste earthen materials, to surface waters of the Lake Tahoe Hydrologic Unit (HU), and specific prohibitions against discharges or threatened discharges within 100 year flood plains and Stream Environment Zones (SEZs). The earliest relevant prohibition, against discharge of "deleterious materials" to surface waters of the Lake Tahoe Basin, was adopted in 1966 (California Regional Water Quality Control Board, 1966). There is also a prohibition (adopted in 1980) against discharges or threatened discharges as a result of impervious surface coverage in excess of the limits of the Lake Tahoe Basin land capability system (the "Bailey System"). For the Heavenly Valley Creek watershed, this prohibition limits any new disturbance to no more than 1% of the "project area", unless the exemption findings set forth in Chapter 5 of the Basin Plan can be made.

Table 1. Beneficial Uses of Heavenly Valley Creek Potentially Affected by Sedimentation.

Beneficial Use	**Definition (from Lahontan Basin Plan)**
Cold Freshwater Habitat (COLD)	Beneficial uses of waters that support cold water ecosystems including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Rare Threatened, or Endangered Species (RARE)	Beneficial uses of waters that support habitat necessary for the survival and successful maintenance of plant or animal species established under state and/or federal law as rare, threatened, or endangered.
Migration of Aquatic Organisms (MIGR)	Beneficial uses of waters that support habitats necessary for migration, acclimatization between fresh and salt water, or temporary activities by aquatic organisms such as anadromous fish.
Spawning, Reproduction, and Development (SPWN)	Beneficial uses of waters that support high quality aquatic habitat necessary for reproduction and early development of fish and wildlife.

C. Interpretation of Narrative Objectives

All of the narrative objectives in Table 2 refer to protection of beneficial uses. The state Nondegradation Policy also requires that beneficial uses be protected even if lowering of water quality is permitted for purposes "of maximum benefit to the people of the State" (e.g., significant socioeconomic benefits).

Waters (1995) provides a comprehensive literature review of the impacts of suspended and deposited sediment on instream beneficial uses. These impacts include coating of “biologically active surfaces” of plants and animals (e.g., fish gills) by clay particles, abrasion and suffocation of attached algae, reduction of light for photosynthesis, and modification of animal behavior (e.g., invertebrate drift). Deposited sediment changes benthic invertebrate habitat in relation to substrate particle size, embeddedness of gravels, and loss of interstitial spaces, leading to changes in species composition and diversity. Suspended sediment may have sublethal effects on fish including reduced feeding and growth, respiratory impairment, and physiological stress leading to reduced tolerance to disease and toxicants. Deposited sediment can have significant impacts on the reproductive success of salmonid fish by filling interstitial spaces in spawning gravels, reducing water and oxygen flow to fish embryos and fry, smothering of embryos and fry, and entrapment of emerging fry.

Watershed disturbance related to ski resort development and maintenance began in the Heavenly Valley Creek watershed well before the adoption of water quality standards for Lake Tahoe and tributary waters. Table 3 includes a chronology of important dates to

Table 2. Narrative Water Quality Objectives for Heavenly Valley Creek Related to Sedimentation.

Title	Objective Text
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in a manner as to cause nuisance or adversely affect the water for beneficial uses.
Settleable Materials	Waters shall not contain substance in concentrations that result in deposition of material that causes nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of settleable materials shall not be raised by more than 0.l milliliter per liter.
Suspended Sediment	Suspended sediment concentrations in streams tributary to Lake Tahoe shall not exceed a 90th percentile value* of 60 mg/L. (This objective is equivalent to the Tahoe Regional Planning Agency's regional "environmental threshold carrying capacity" standard for suspended sediment in tributaries.) *The Regional Board will consider revision of this objective in the future if it proves not to be protective of beneficial uses or if review of monitoring data indicates that other numbers would be more appropriate for some or all streams tributary to Lake Tahoe*.

* In this case, a 90th percentile value means that no more than 10 percent of all samples should have suspended sediment concentrations greater than 60 mg/L.

consider in defining baseline conditions for the interpretation of narrative objectives, including the nondegradation objective, and for determining the TMDL loading capacity.

The first available quantitative study of suspended sediment impacts on beneficial uses of Heavenly Valley Creek is that by Baker and Davis (1976), who sampled suspended sediment and macroinvertebrate communities at several stations between 1972 and 1974. Baker and Davis documented increased suspended sediment concentrations, and increased degradation of macroinvertebrate communities, at downstream stations below the area of greatest watershed disturbance. Earlier sediment studies of Tahoe Basin streams (not including Heavenly Valley Creek) were concerned with documenting highways and urban development on sediment loading to Lake Tahoe, and not with instream beneficial uses.

Baker and Davis described then-existing development in the Heavenly Valley Creek watershed as follows (emphasis added):

> *"This watershed is dominated by ski trails which were stripped of vegetation when constructed. Other man-made disturbances include access roads, ski lift operations, stream crossings and random trails and roads developed by off-road vehicles."*

For purposes of the TMDL analysis, Regional Board staff assume that the watershed was significantly developed, and the creek's aquatic life uses were significantly affected by sediment, at the time that the Nondegradation Policy was adopted. This is important in evaluating the degree of beneficial use support required for compliance with the narrative objectives. (See the loading capacity linkage analysis section below.) Due to the implementation of erosion controls, and probable ecosystem recovery over time, current watershed conditions are assumed to represent improvement over those existing at the time the first applicable standard (the Nondegradation policy) was adopted. The extent of current aquatic life use support is unknown. The TMDL focuses on maximizing beneficial use support to the extent practicable. Progress toward enhancement of beneficial uses and attainment of narrative objectives will be defined in terms of improving trends in the parameters connected with the instream numeric targets discussed below.

D. Summary of Historic and Existing Concerns

In general, compared to the reference stream, Heavenly Valley Creek has higher suspended sediment concentrations, and more disturbed channel conditions. Suspended sediment concentrations have historically exceeded the 60 mg/L 90th percentile water quality objective. Modeled hillslope sediment delivery to the creek was about 14.5 times higher in 1995 than the estimated natural sediment delivery rate. Two different multiparameter indices of stream channel condition show significant problems in Heavenly Valley Creek. There is evidence of degradation of benthic macroinvertebrate communities as early as 1972, and fish habitat quality has been rated "marginal" since 1982. The following is a more detailed summary of concerns related to specific problem areas. The discussion of numeric targets below includes additional information on "existing" instream and hillslope conditions.

1. Instream Conditions.

Suspended Sediment. The reported annual mean suspended sediment concentration in Heavenly Valley Creek between 1970 and 1976 was higher than that in several other Tahoe Basin streams with relatively undisturbed watersheds (Skau and Brown, 1988). Baker and Davis (1976) found increased concentrations of suspended sediment at downstream stations in Heavenly Valley Creek, and high overall concentrations compared to a station above all disturbance on another Lake Tahoe Basin stream with a decomposed granite watershed. Baker and Davis were unable to find a reference station above all disturbance on Heavenly Valley Creek. Violations of the Tahoe Regional Planning

Agency's "environmental threshold" standard for suspended sediment (equivalent to the Regional Board's subsequently adopted 60 mg/L objective) occurred during the 1980s (TRPA, 1995).

Evaluation of U.S. Forest Service monitoring data (Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999) shows that the numerical suspended sediment objective (60 mg/L as an annual 90th percentile value) was attained at most Heavenly Valley Creek stations in 1997 and 1998, although “borderline” violations occurred at the station farthest downstream. Annual mean suspended sediment concentrations for different Heavenly Valley Creek stations in 1997 ranged from 2.3 to 31.4 mg/L. The range in 1998 annual means was 8.0 to 20.6 mg/L. Annual mean concentrations for the reference stream, “Hidden Valley Creek” were 3.1 mg/L in 1997 and 4.0 mg/L in 1998. Both 1997 and 1998 were years with above average precipitation.

Stream Channel Conditions. By 1974, 200 yards of Heavenly Valley Creek had been placed within a culvert; Sky Meadow Reservoir was constructed in 1978. The culvert and reservoir have been identified as obstacles to fish migration, and obviously do not function as natural stream segments. The alterations to natural flow regimes as a result of diversions for snowmaking has been identified as a fish habitat concern, and altered flows may affect channel conditions.

In 1990, stream channel stability in Heavenly Valley Creek and Hidden Valley Creek was rated using the Pfankuch stream stability rating system. (No specific publication was cited for the Pfankuch methodology used in 1990; Hazelhurst et al. [1999] cite Pfankuch, 1978].) The overall Pfankuch rating for Heavenly Valley Creek was “fair to poor”, and observations included sedimentation quite evident throughout the creek, with deposits found filling pools and behind debris jams, log rounds from cut trees often found in one reach of the creek, and obstructions to flow such as hay bales in upper reaches of the creek, with some cutting around obstructions. The overall Pfankuch rating for Hidden Valley Creek, the reference stream, was “good”.

Table 3. Chronology for Evaluating Baseline Conditions for Compliance with Narrative Objectives

Date	Event
1956	Ski resort development begins in Heavenly Valley Creek watershed
1960	First diversions from Heavenly Valley Creek for resort use
1965	USFS begins erosion control work at Heavenly Ski Resort
1966	Lahontan Regional Board adopts prohibition against discharge of "deleterious materials" to surface waters of Lake Tahoe Basin
1968	California State Water Resources Control Board adopts Resolution 68-16, the statewide "Nondegradation Policy"
1969 -71	Studies of other Tahoe Basin streams document increased sedimentation in developed watersheds (Glancy 1973; Kroll, 1969)
1970-76	Skau and Brown (1988) study of suspended sediment loading in central Sierra streams including Heavenly Valley Creek
1971	Regional Board prohibits discharges or threatened discharges to 100 year flood plains of Lake Tahoe and its tributaries
1971	Regional Board adopts Interim Basin Plan (not approved by the USEPA)

	including narrative objective for "bottom deposits"
1972	Federal Clean Water Act, including "fishable/swimmable" goals, adopted
1972-74.	Regional Board staff study of Heavenly Valley Creek shows elevated suspended sediment levels and degradation of invertebrate communities downstream of ski resort development (Baker and Davis, 1976)
1973-74	Baker and Davis study cites USFS implementation of an erosion control project in the Heavenly Valley Creek watershed
1975	Regional Board adopts the *Water Quality Control Plan for the North Lahontan Basin*, including sediment-related objectives
1975	USEPA Water Quality Standards Regulation (40 CFR 131) which includes the federal antidegradation regulations, takes effect
1977	California Tahoe Regional Planning Agency adopts "*Criteria for the Development and Expansion of Ski Areas, Lake Tahoe Basin*" including BMP and monitoring requirements
1978	Sky Meadow dam and reservoir constructed
1980	State Water Resources Control Board adopts Lake Tahoe Basin Water Quality Plan, designating Lake Tahoe an Outstanding National Resource Water and strengthening regulatory controls through prohibitions related to the land capability system

The USFS is monitoring riparian condition in four stream reaches annually on a rotating basis using the USFS Stream Condition Inventory (SCI) procedure. Two reaches of Heavenly Valley Creek are included in the overall program. These reaches were surveyed in 1996 (Hazelhurst and Widegren, 1998). One reach is located in Sky Meadows and the other downstream near the ski area boundary. Six permanent stream cross sections were established during this survey and resurveyed in 1997. Most of the permanent stream cross sections, and new randomly selected cross sections were surveyed in 1998 (Hazelhurst *et al*. 1999). This report concludes (page 5-9):

> *"The SCI cross-sectional surveys performed on two reaches of Heavenly Valley Creek show some changes in channel morphology. The permanent cross-sections on both reaches have degraded since the 1997 survey, indicating net loss of material on the channel bottom. The random cross-sections indicate that reach HVC-1 is becoming narrower and deeper while reach HVC-2 is becoming shallower and wider".*

Reach HVC-1 is located in Sky Meadows (the relatively flat area near the reservoir); Reach HVC-2 is located near the ski resort boundary. The Hazelhurst *et al.* report includes additional data comparing stream cross sections within these two reaches and bankfull width measurements from random transects within the reaches, over two to three year monitoring periods. The transects showed "notable increases in bankfull width between the 1997 and 1998 surveys" for both reaches. However, because the transects were random, some of the difference could be attributed to variance in their locations.

Table 4. Historic Suspended Sediment Concentration Data for Heavenly Valley Creek and Other Tahoe Basin Streams (Values are annual means unless otherwise indicated.)

Stream and Years Sampled	**Suspended Sediment (mg/L)**	**Reference**

Heavenly Valley Cr., 1970-1976	29.7 (annual); 6.4 (non-snowmelt); 83.7 (snowmelt)	Skau and Brown, 1988
Heavenly Valley Cr. 1972-74	3.9 (dry season); 150 (runoff period)	Baker and Davis, 1976
Heavenly Valley Cr. 1980-1989	Range about 5-115	TRPA, 1995
Heavenly Valley Cr., 1997-1998	20.6-31.4	Hazelhurst and Widegren, 1998; Hazelhurst et al. 1999
Hidden Valley Creek, 1997-1998	3.1-4	Hazelhurst and Widegren, 1998; Hazelhurst et al. 1999
Lonely Gulch Creek, 1973-74	1.2- 4.16 mg/L (runoff period)	Baker and Davis, 1976
General Creek 1970-1976	10.1	Skau and Brown, 1988
Meeks Creek 1970-1976	4.5	Skau and Brown, 1988
Eagle Creek, 1970-1976	5.8	Skau and Brown, 1988

Aquatic Habitat Concerns. Between 1972 and 1974 Baker and Davis (1976) took Surber samples of benthic macroinvertebrates at several stations in Heavenly Valley Creek downstream of various amounts of watershed disturbance. Baker and Davis concluded that, compared with reference stations, downstream stations in disturbed areas had significant decreases in diversity, numbers and standing crop biomass of macroinvertebrates. Several genera of insects were eliminated at downstream stations. No later macroinvertebrate data are available for the listed segment of Heavenly Valley Creek.

The Tahoe Regional Planning Agency has regional "environmental threshold carrying capacity" standards for fish habitat quality, and reports on the attainment status of these and other standards at five year intervals. TRPA (1996) reported, based on U.S. Forest Service habitat surveys of Heavenly Valley Creek, that its fish habitat quality index rating in 1982 and 1996 was "marginal", and that the score *decreased* between 1982 and 1996. (The 1996 rating was probably based on the 1990 USFS survey summarize in TRPA.) The "marginal" classification is at the lower end of a "marginal" to "good" to "excellent" spectrum based on a point system; the 1982 score of 26 declined to 14 in 1996. The TRPA analysis indicated that the score could be upgraded to "excellent" (42 points) by increasing pools, improving substrate, shade canopy, and bank/channel stability, and removing barriers and diversions. (See the implementation section below for a summary of a proposed two phase fish habitat improvement project which would address these concerns.)

The only fish found in the listed segment of Heavenly Valley Creek in 1990 were seven Lahontan cutthroat trout. The population was probably established from trout planted in Sky Meadow Reservoir in 1980 and washed downstream during high flows in 1983. No Lahontan cutthroat trout were found in the creek in another survey in 1995. Heavenly Valley Creek is not identified in the USFWS's 1995 "Recovery Plan for the Lahontan Cutthroat Trout, January 1995". In 1996, the LTBMU stated its intent to continue monitoring the creek for the trout between 1995 and 2000, and if trout were observed, to initiate consultation with the USFWS (Harris, 1996; TRPA, 1995).

2. Hillslope Conditions

In 1988 the LTBMU included the following statement in the "Issues, Concerns, and Opportunities" section of its Forest Plan's "Management Area Direction" for the Heavenly Management Area:

> *"Removal of boulders, tree stumps and other obstacles, as well as shaping of terrain on ski trails, has resulted in substantial soil disturbance leading to high rates of soil erosion and nutrient transport to Lake Tahoe. The decomposed granite soils are difficult to stabilize and revegetate. Since about 1965, major efforts have been made to stabilize eroding areas and establish protective cover of low vegetation at a cost in excess of $3 million. Although many acres of disturbed area have been stabilized, water quality standards have not been attained for much of the area. Major failures of some erosion structures occurred during a severe localized summer thunderstorm in 1983, requiring extensive repairs."*

(The Heavenly Management Area includes other watersheds in addition to that of Heavenly Valley Creek.) The problems described above prompted the LTBMU to develop the sediment delivery model described in Appendix 1, and to quantify relative sediment delivery rates from ski runs, roads, and undisturbed areas.

Section 3.2. Numeric Targets

Section 303(d) (1) C) of the Clean Water Act states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards". The numeric targets developed for the Heavenly Valley Creek sediment TMDL are intended to interpret the narrative and numeric water quality objectives, which in turn provide for support of designated beneficial uses. Under existing law, numeric targets for TMDLs are goals, not enforceable water quality standards. The Regional Board can take enforcement action, consistent with the TMDL, for actual or threatened discharges to surface waters which violate applicable water quality standards (including beneficial uses and narrative and numeric water quality objectives).

The USEPA's protocol for developing sediment TMDLs (1999) states that in many cases it may be difficult to relate sediment mass loading levels to beneficial use impacts or source contributions because the variation of sediment yields with space and time make it difficult to derive meaningful "average" conditions, and to compare existing conditions with natural or background conditions. The protocol identifies alternative approaches to mass loading as a numeric target, including targets related to instream indicators such as substrate or channel condition, and aquatic biota. It also identifies potential hillslope indicators to complement instream indicators and targets. The use of multiple targets and indicators is advantageous in that it compensates for uncertainty about the effectiveness of individual indicators. Multiple indicators can also account for complex ecological processes including seasonal and annual differences in pollutant levels by measuring net long term change (USEPA, 1999, 2000). A variety of instream and hillslope indicators and targets have been identified for Heavenly Valley Creek, to complement the instream suspended sediment loading target reflected in the load allocations.

The instream numeric targets for Heavenly Valley Creek are desired future stream habitat conditions for fish and aquatic invertebrates, and provide a set of criteria for interpretation of the long term recovery of the aquatic life-related uses affected by sedimentation. The hillslope numeric targets measure the success of the implementation program in reducing sediment delivery to the creek. If these targets are attained, erosion rates and sediment delivery should decline to levels which will allow instream habitat and beneficial uses to recover, over time, from the impacts of excessive sedimentation in the past. The numeric targets are based on scientific literature, available monitoring data for the Heavenly Valley Creek and Hidden Valley Creek watersheds, and the LTBMU model described in Appendix 1 to this staff report.

Tables 5 and 8 summarize instream and hillslope numeric targets for the TMDL and the availability of data on existing and reference conditions. More detailed discussions of targets in relation to existing conditions are provided in the text below. Attainment of most of the instream targets will be measured in comparison to conditions in the reference stream, Hidden Valley Creek.

A. Instream Numeric Targets

The instream numeric targets in Table 5 were selected because they provide a range of physical, chemical, and biological indicators and because most of these parameters are already being monitored in Heavenly Valley and Hidden Valley Creeks. The LTBMU monitors several stations on Heavenly Valley Creek. Compliance with targets and load allocations will be evaluated at the "Property Line" station which is the farthest downstream and which has been used as the compliance point for waste discharge requirements for many years.

1. Suspended sediment concentration.

Suspended sediment concentration was chosen as an indicator because it is directly related to water quality objectives and load allocations, and because the long period of record for suspended sediment in Heavenly Valley Creek and other Lake Tahoe Basin streams will facilitate evaluation of improving trends in the future.

a. Numeric target

The numeric target is an annual mean suspended sediment concentration at the "Property Line" station, expressed as a 5 year rolling average, no greater than that observed in the reference stream, Hidden Valley Creek. (A 5 year rolling average is the arithmetic mean of 5 contiguous annual means. For example, in the fifth year, the mean of annual averages for years 1-5 will be calculated. In the sixth year, a new mean, based on years 2-6 will be calculated, and so on.) Since the 90th percentile suspended sediment concentration for Hidden Valley Creek is far below the 60 mg/L, 90th percentile numeric water quality objective for tributaries of Lake Tahoe, the use of a target based on five year rolling average conditions in Hidden Valley Creek will not be an issue which will cause misinterpretation of the data in regard to the numeric objective. This target will ensure compliance with both the numerical objective and the narrative objectives related to protection of beneficial uses.

b. Comparison of numeric target and existing conditions.

Table 4 above summarizes historical annual mean suspended sediment concentrations reported for Heavenly Valley Creek, Hidden Valley Creek, and other streams in the Lake Tahoe Basin with relatively undisturbed granitic watersheds. Although erosion control projects have been implemented in the Heavenly Valley Creek watershed for many years, the historical suspended sediment data cannot necessarily be interpreted to show improvements due to BMPs. Complicating factors include the episodic nature of suspended sediment concentrations even in “normal” water years, a lengthy drought period, several mass wasting incidents which required repair of BMPs, and changes in the monitoring program over time.

2. Total instream sediment load.

a. Numeric target

The numerical target for total instream sediment loading in Heavenly Valley Creek is 53 tons/year, expressed as a five year rolling average. This number reflects the modeled maximum feasible reduction in sediment leading with full application of BMPs to the watershed. It is believed to be close to natural conditions and reasonably comparable with the estimated 45 tons per year total sediment load in Hidden Valley Creek. The watershed of the monitored segment of Hidden Valley Creek is about 87 % of the size of Heavenly Valley Creek's watershed (1162 acres compared to 1341 acres). If Hidden Valley Creek's estimated total sediment load were increased by 13%, it would about 51 tons per year.

b. Comparison of numeric target and existing conditions. The estimated historic total (suspended and bedload) sediment loads for Heavenly Valley Creek and Hidden Valley Creek are 150 and 45 tons per year, respectively. (See the Source Analysis section, below.)

3. Pfankuch channel stability rating

The Pfankuch channel stability index (Pfankuch, 1978) involves rating 15 different parameters affecting stream stability while walking the length of the reach. Factors include riparian vegetation, cut banks, sand deposition, degree of scour, etc. The index rates stability for each reach as "Poor", "Fair", or "Good", and the LTBMU compares results of different surveys to rate trends for each reach with terms such as "Same", "Degenerating", "Improved", "Much Improved" (Hazelhurst and Widegren, 1998).

a. Numeric target.

The Pfankuch index ratings for monitored reaches of Heavenly Valley Creek should show an improving trend over time from "fair-poor" " to "good" (the rating for Hidden Valley Creek).

b. Comparison of numeric target and existing conditions

In 1990, the most recent year in which Pfankuch surveys were done, LTBMU staff rated Heavenly Valley Creek as "fair-poor" and Hidden Valley Creek as "good". More recent Stream Condition Index ratings are available for Heavenly Valley Creek (see the next section).

4. Stream Condition Index

The U.S. Forest Service, Pacific Southwest Region, uses a "Stream Condition Index", which also measures a number of variables affecting channel condition. The procedure includes classification of reaches using the Rosgen system; surveys of stream cross sections to detect aggrading or degrading conditions and thus movement of sediment; and changes in gradient, which also indicate downcutting and loss of bed material (Hazelhurst and Widegren, 1998).

In review of earlier drafts of the TMDL and implementation program, the Regional Board's scientific peer reviewer (Kondolf, 1999) criticized the applicability of the Pfankuch stability rating and Rosgen channel classification systems to the Heavenly Valley Creek situation, and suggested that changes in actual channel conditions be measured (including measurement of bed sediment through procedures such as the pebble count, and documentation of channel form through repeat surveys). The SCI includes both stream channel measurements and pebble counts. Pfankuch surveys are recommended as a TMDL indicator *in addition to* the SCI surveys to permit trend analysis in comparison with earlier results.

a. Numeric target

Over time, Heavenly Valley Creek should show a trend of increasing stability, and the SCI rating should approach that of Hidden Valley Creek.

b. Comparison of numeric target and existing conditions.

SCI surveys for Heavenly Valley Creek between 1996 and 1998 (Hazelhurst *et al*., 1999) show aggradation and degradation linked to annual differences in runoff; see the "problem statement" discussion above. SCI ratings are not yet available for Hidden Valley Creek.

<u>5. Macroinvertebrate community health</u>

Macroinvertebrate community health will be evaluated using the protocol developed by the Regional Board's consultant (University of California, Sierra Nevada Aquatic Research Laboratory) to provide the basis for eventual adoption of "biocriteria" water quality objectives. A description of this protocol is included in Section 5.4 below.

a. Numeric target

Over time, there will be improving trends in macroinvertebrate habitat quality and community metrics, and macroinvertebrate communities in Heavenly Valley Creek will be more similar to those in Hidden Valley Creek. (Once biocriteria have been adopted, the target may be changed to use more specific biocriteria metrics as indicators of adequate beneficial use support.)

b. Comparison of numeric target and existing conditions.

No recent biomonitoring data are available for Heavenly Valley and Hidden Valley Creeks. As noted above, Baker and Davis (1976) observed degradation of macroinvertebrate communities at stations in Heavenly Valley Creek downstream of ski resort development in the early 1970s. Due to differences in sampling protocols, it will not be possible to compare the Baker and Davis Surber sampling data directly with data obtained using current bioassessment methods (Thomas Suk, personal communication). The more recent fish habitat and stream channel studies summarized elsewhere in this staff report indicate that habitat conditions are still not optimal for macroinvertebrates in Heavenly Valley Creek.

B. Hillslope Numeric Targets

The hillslope targets in Table 8 were selected because they provide different ways of measuring the success of the implementation program, and because they are already being monitored by the LTBMU in the Heavenly Valley Creek watershed.

Table 5. Instream Indicators and Targets for Heavenly Valley Creek TMDL

Indicator	Target Value(s)	Reference
Suspended Sediment		
Suspended sediment concentration	Concentration no greater than annual average for Hidden Valley Creek during a year with similar precipitation and runoff.	Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999.
Instream total sediment load	Maximum 53 tons/year as a 5 year rolling average.	Data from Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999; unpublished LTBMU data, calculations by Stefan Lorenzato, SWRCB

Geomorphology Measures		
Pfankuch channel stability rating (composite rating includes numeric scores for 15 different indicators)	Increasing trend over time from "fair-poor" to "good" (comparable with overall rating of Hidden Valley Creek)	1990 Pfankuch method surveys by LTBMU staff of both creeks (TRPA, 1995, Appendix E)
USFS Region 5 "Stream Condition Index" (SCI)	Improving trends in channel morphology over time	Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999.
Biological Indicators		
Macroinvertebrate community health.	Improving trends in benthic invertebrate community metrics over time, approaching conditions in Hidden Valley Creek.	Baker and Davis, 1976 UC-SNARL bioassessment protocol (Thomas Suk, personal communication.)

1. Watershed disturbance (Percent Equivalent Roaded Area)

"Equivalent Roaded Area" is a term used in the USFS model (Holland, 1993) and the Heavenly Master Plan EIS (TRPA, 1995, 1996) as an index of watershed disturbance in relation to sediment delivery. An "equivalent roaded acre" is defined in terms of a standard road with specific characteristics, and the sediment delivery rate from this type of road in the Heavenly Ski Resort is modeled as 5 tons per acre. The "Percent Equivalent Roaded Area" index is calculated by dividing total equivalent roaded acres by the watershed area (1341 acres for the Heavenly Valley Creek watershed.) Percent ERA is proposed as an indicator for the TMDL because it is a simple indicator of the degree of restoration of disturbed areas over time. The USFS has adopted ERA targets for road and ski run categories as part of the erosion control program in the Heavenly Ski Resort Master Plan, and progress toward attainment of these targets is already being monitored and reported on (see USFS, 1998).

a. Numeric targets

The numeric target is reduction of watershed disturbance to a maximum of 2 percent ERA, based on the mitigation goal in the Heavenly Ski Resort Master Plan EIS (TRPA, 1995, 1996) and on estimated hillslope sediment delivery after full mitigation.

b. Comparison of numeric target and existing conditions

The LTBMU model estimated total ERA for the Heavenly Valley Creek watershed as 7.87 percent in 1995 and documented percent ERA for each modeled road and ski run segment (TRPA, 1995).

2. Effective soil cover.

Effective soil cover includes cover by living plants, downed woody debris, organic matter, and rocks (Hazelhurst and Widegren, 1998). As noted in the description of the watershed above, vegetative cover is naturally sparse in some parts of the watershed. The USFS model establishes specific percent cover targets for each specific road and ski run segment. Improvements in percent cover are measured by annual resampling of a number of randomly selected roads and ski runs in the ski resort as a whole.

a. Numeric target

Over time, the LTBMU's modeled cover targets for specific road and ski run segments within the Heavenly Valley Creek watershed should be met. Using the criteria in Tables 6 and 7, the overall percent cover ratings for roads and ski runs within the Heavenly Valley Creek watershed should be "good" or better.

b. Comparison of numeric target and existing conditions.

The LTBMU measured percent cover for individual road and ski run segments in 1991 during development of the model. Model results include specific targets for each segment. The LTBMU evaluates percent cover annually and uses the criteria in Tables 6 and 7 in its annual evaluations of ski runs and roads.

In 1997, the USFS (Hazelhurst and Widegren, 1998) sampled soil cover (by vegetation, organic matter, or rocks, as opposed to “bare” area) on 35 ski run and road segments randomly chosen from the resort as a whole, not only in the Heavenly Valley Creek watershed. Average cover on these runs had increased by 11% from levels measured in

Table 6. LTBMU Evaluation Criteria for Ski Runs (Hazelhurst *et al.*, 1999)

Rating	**Cover**	**Erosion**	**Mitigation**
Excellent	>70%	none	none
Good	>50%	little (sheet)	spot work
Fair	<50%	moderate (rills)	entire segments
Poor	<30%	heavy (gullies)	entire area

Table 7. LTBMU Evaluation Criteria for Roads (Hazelhurst *et al.*, 1999).

Rating	**Road Surface Rilling**			**Cut and Fill Slopes**	
	Extent	***Length***	***Depth***	***Erosion***	***Cover***
Excellent	none	none	none	none	>70%
Good	lite	<10m (30 ft)	<3 cm) 1 in	sheet; no fans/plumes	>50%
Fair	moderate	<31m (100 ft)	<10 cm (4 in)	rills; small fans/plumes	<50%
Poor	heavy (gullies)	>31 m (100 ft)	>10 cm (4 in)	gullies; large fans/plumes	<30%

Table 8. Hillslope Indicators and Targets for Heavenly Valley Creek TMDL

Indicator	Target Value(s)	References
Percent Equivalent Roaded Area (ERA)	USFS targets and schedules for ERA reduction for ski run and road categories and for watershed as a whole; progress reported annually and evaluated at 5 year intervals.	TRPA 1995, 1996
Effective soil cover (vegetation, woody debris, organic matter, rocks) on ski runs and roads	Cover meets modeled mitigation targets set for specific road/run segments in watershed, and overall cover rating is "good" or better using criteria in Tables 6 and 7	TRPA 1995, 1996; Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999.

1991. In 1998 (Hazelhurst *et al.*, 1999) soil cover was assessed on 18 ski runs (over the resort as a whole) using fixed plots and random transects. The overall average for total coverage was 65%, up 18 percent from 1991. The range of total cover was 41% (on an older run) to 91% (on two newly cut runs where "state of the art" BMPs were used). Using the criteria in Table 6, ski run cover was between "good" and "excellent" for the sampled runs in 1998. Information is not available to provide a current overall rating for the runs in the Heavenly Valley Creek watershed.

Section 3.3. Source Analysis

Historic and potential future sediment sources in the watershed of the listed segment of Heavenly Valley Creek are nonpoint sources. There are no point sources within the watershed, and therefore this TMDL does not include wasteload allocations. As noted above, the scope of the TMDL analysis is limited to the upper portion of the Heavenly Valley Creek watershed, on National Forest land administered by the LTBMU, within the Heavenly Ski Resort permit boundaries. Because this subwatershed is within a single ownership, the source analysis emphasizes land disturbance categories, rather than dischargers. The source analysis below summarizes the results of (1) modeling by the LTBMU to quantify sediment delivery to Heavenly Valley Creek from various hillslope sources; and (2) calculations by State and Regional Board staff to estimate the existing instream suspended sediment loads attributable to different hillslope sources. In the source analysis, and elsewhere in this TMDL, loading figures are rounded to the nearest ton and expressed in English, rather than metric tons.

A. Data and Methods Used

The hillslope sediment source analysis is based upon results from the sediment delivery model described in Appendix 1, which was developed by the U.S. Forest Service, LTBMU. The model in turn uses several procedures described in the "WRENNS Handbook" (USFS, 1980) and the *Guide for Predicting Sediment Yields from Forested Watersheds* (USFS, 1981). The *Guide* is based on research in the Idaho Batholith, an area with decomposed granitic soils similar to those in the Lake Tahoe Basin. The WRENNs methodology involves segmenting watersheds into land types and land system inventories, and then allocating values for erosion hazard potential and sediment delivery ratios, to allow generation of erosion curves for each disturbance source in the watershed. Sediment delivery is estimated using a "Modified Universal Soil Loss Equation" from the WRENNS Handbook, with adjustments for rill and gully erosion and other modifications based on the Idaho batholith studies.

In 1991, USFS staff collected field data on 383 road, ski run, and undisturbed "segments" within the Heavenly Valley Creek watershed for input into the model. (The term "segment" is not defined by the LTBMU, but is apparently used in a similar sense to the Washington Forest Practices Board's (1997) definition of "road segments" as road lengths with generally similar characteristics such as topography and construction practices.) For all ski runs and roads, the segment acreage, slope length, gradient, percent canopy and cover (by vegetation, duff, etc.) were measured, and existing erosion control structures were evaluated. The LTBMU also modeled suspended sediment yield from undisturbed lands, using several different methods summarized in the Appendix. The Appendix also summarizes the model output data used in the TMDL source analysis. Although modeled "existing" sediment delivery is expressed as tons per year per disturbance category for the watershed as a whole, sediment delivery generally occurs as a long term process, with considerable seasonal and annual variation. The LTBMU model will be calibrated, using subsequent monitoring data including direct measurements of erosion, during the winter of 2000-2001 (Sherry Hazelhurst, USFS, personal communication).

Regional Board staff's initial approach to the Heavenly Valley Creek sediment TMDLs relied only on the hillslope modeling data. Comments on earlier drafts by the scientific peer reviewer (Kondolf, 1999) and by USEPA and State Water Resources Control Board staff led to a revised approach to source analysis and load allocations. Instream suspended sediment loads were calculated from instantaneous sediment concentrations and instantaneous flow values reported by the LTBMU for Heavenly Valley Creek between 1996 and 1999 (Hazelhurst and Widegren, 1998; Hazelhurst *et al*., 1999, and unpublished LTBMU data), and a spreadsheet model suggested by Dr. Kondolf. The calculation procedure is described below. Dr. Kondolf's calculations and the TMDL spreadsheet calculation results will be included in the administrative record of the Basin Plan amendments.

Sampling dates were converted to Julian dates, and added in decimal fractions of the dates to reflect sampling time during the day. Flows were converted from cubic feet per second to cubic meters per second, and flow was multiplied by suspended sediment concentration expressed as kilograms /cubic meter to yield kilograms/second (the sediment transport rate). The transport rate was multiplied by the number of days preceding the sampling date to obtain the total load in the interval since the previous sample. These values were combined to obtain cumulative kilograms of sediment transport over the year and converted to tons/year for comparison with the LTBMU sediment delivery estimates. This approach generally applies a given sediment concentration to all days between a given sample and the preceding sample, usually about one week. Exceptions were made for samples collected during a July 28,1997 thunderstorm: see Kondolf (1999).

Stefan Lorenzato, the State Water Resources Control Board's TMDL coordinator, performed Excel spreadsheet calculations using the procedure above and data for 1996 through 1999 for Heavenly Valley Creek. The modeled "existing" suspended sediment load for these four years was 93 tons per year. Assuming that this value is 80 percent of the total (with bedload 20 percent), the total "existing" sediment load was 116 tons/year. Bedload sediment data are not available for Heavenly Valley and Hidden Valley Creeks, but the literature (Woyshner and Hecht, 1988) suggests that in relatively undisturbed areas of the Lake Tahoe-Truckee region bedload sediment could be expected to be 15-20%.

Sherry Hazelhurst of LTBMU staff pointed out that suspended sediment loads calculated from monitoring data collected in the late 1990s should be expected to reflect water quality improvement as a result of BMPs already implemented. Using Ms. Hazelhurst's estimate of the effectiveness of BMPs implemented to date, the monitored sediment load was used to back-calculate the "total unmitigated load" of sediment to Heavenly Valley Creek as 150 tons/year. These calculations assumed that 75 percent of the planned BMPs have already been implemented, and that they are at 40-50 percent of their potential efficiency. Therefore, the BMPs are now achieving 35 percent of their expected control capability. Assuming that the BMPs will ultimately be 65 percent effective overall, about

22.75 percent (that is, 35% capability x 65% effectiveness) of the sediment load is now controlled. The total unmitigated load (150 tons per year) was obtained by multiplying the 116 tons/year load calculated from monitoring data by 0.7775.

Assuming a 1:1 relationship between hillslope sediment delivery and total instream sediment loads, the instream loads were apportioned among source categories based on percentage of the total from each category. The current TMDL analysis assumes that over the long term, sediment input will equal sediment output in a properly functioning stream. Therefore, the instream sediment loading estimate and the load allocations below do not account for instream sediment storage as a source or sink.

Table 9. Estimated Instream Total Sediment Loads for Heavenly Valley and Hidden Valley Creeks

	Total (Suspended + Bedload) Sediment Loads (tons/year)
Heavenly Valley Creek (estimated from monitoring data for 1996-99 Stefan Lorenzato, SWRCB)	116
Heavenly Valley Creek, estimated unmitigated load	150
Hidden Valley Creek (1991-1999, from unpublished LTBMU data)	45

B. Source Categories

The Heavenly Valley Creek TMDL groups hillslope sediment sources into the same categories used in the USFS sediment delivery model: unpaved roads, ski runs, and undisturbed lands. The modeling results do not distinguish between source areas in California and Nevada. The ski run and road categories are grouped separately in the USFS modeling results, and were modeled differently in that a separate coefficient was used to account for soil compaction on roads.

The USFS also measured impervious surface coverage (buildings, pavement, etc.) in the watershed (0.67 acres as of 1995), but did not include it as a sediment source in the model. Regional Board staff recognize that impervious surface coverage can affect erosion and sediment delivery by increasing runoff intensity. However, mitigation for increased surface runoff from impervious surface in the Heavenly Valley Creek watershed was provided separately from mitigation for modeled sediment delivery in the Heavenly Ski Resort Master Plan EIS (TRPA, 1995, 1996); the 1995 impervious surface was to be reduced to 0.13 acres. For purposes of the TMDL, the impacts of mitigated impervious surface on sediment delivery are assumed to be "de minimis", and this category is assigned a zero value in the source analysis and load allocations.

As noted in the Land Use section above, undeveloped lands in the Heavenly Valley Creek and Hidden Valley Creek watersheds may have been disturbed by 19th century logging and grazing. However, the high quality of Hidden Valley Creek indicates that, at least in terms of sediment delivery, these lands have recovered to natural or near natural levels. The estimated natural soil loss from the Heavenly Valley Creek watershed as a whole was 0.03 tons per acre per year. (Because of a discrepancy in the watershed area used in calculation of the total sediment yield for undeveloped lands which was used in the Master Plan EIS, Regional Board staff recalculated the yield using the 1341 acre watershed size used for yields for other source categories. The total modeled "existing" sediment yield becomes 559 tons/year rather than the 583 tons/year derived from the EIS. The derivation of the LTBMU's natural sediment yield figure is explained in the Appendix. This figure is within the range of sediment yields calculated from field measurements for other Lake Tahoe Basin streams and stream stations with relatively undisturbed watersheds (White and Franks, 1978; Rowe, 1998; Skau and Brown 1988).

Table 10 summarizes the modeled "existing" (1995) hillslope sediment delivery from different hillslope sources, and shows that 94 percent of the sediment delivery to Heavenly Valley Creek can be attributed to human activities. Table 11 apportions the calculated "existing" (1996 through 1999 loads) instream total sediment load among the hillslope sources using the same percentages of the total anthropogenic load.

Table 10. Source Analysis for Sediment Delivery to Heavenly Valley Creek.
(Sediment delivery figures are for the 1341 acre watershed.)

Source Category	Area (acres)	Sediment Delivery (tons/year)	Percent of Total Load
Roads	19	349	62
Ski Runs	182	176	32
Impervious surface	1	0*	0*
Undeveloped Area	1119	34	6
TOTAL	**1341**	**559**	**100**

* Sediment delivery from impervious surface is considered "de minimis".
** Number rounded upwards

Comparison of the calculated instream total sediment loads with estimated hillslope sediment yields from the LTBMU model (Tables 10 and 11) implies that the model greatly overestimated sediment delivery. However, it should be noted that the model is based on field measurements taken in 1991. Some erosion control work was done between 1991 and 1996, and intensive work under the master plan program began in 1996. The LTBMU (1998) estimated that restoration work done in the Heavenly Valley Creek watershed during 1998 alone was enough to reduce long term sediment loading by 159 tons per year. Therefore, the differences between the LTBMU's modeled data and the calculated instream sediment data may reflect reductions in sediment delivery since 1991 as well as the limitations of the model.

Table 11. Estimated Sources of Instream Sediment Loading to Heavenly Valley and Hidden Valley Creeks (Total suspended plus bedload sediment; values are rounded to the nearest ton.)

Source Category	**Loading (Tons/Year)**	**Percent of Total**
Heavenly Valley Creek		
Roads	93	62
Ski Runs	48	32
Undisturbed Lands	9	6
Impervious Surface	0	0
TOTAL	150	100%
Hidden Valley Creek		
Undisturbed Lands	45	100%
TOTAL	45	100%

Section 3.4. Loading Capacity Linkage Analysis

"Loading capacity" is the maximum amount of a pollutant a water body can assimilate and still meet its water quality standards. TMDL documents must describe the relationship between numeric targets and identified pollutant sources, and estimate the loading capacity for the pollutant of concern. The USEPA Region IX *Guidance for Developing TMDLs in California* (2000) states that the loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL, and that the linkage analysis section must discuss the methods and data used to estimate loading capacity.

It is difficult to predict precise relationships between hillslope sediment delivery and instream conditions, because linkages are often indirect (e.g., there may be a lag of years or decades between hillslope erosion and effects on instream uses), and because there is inherent seasonal and annual variability in hillslope erosion processes and instream physical, chemical and biological community conditions. Nevertheless, it is obvious from the literature in general and from studies at Heavenly Valley Creek in particular that watershed disturbance increases sediment delivery and that increased sediment delivery affects instream water quality and beneficial uses. The USEPA (1999) protocol for developing sediment TMDLs states that linkage analyses can be less precise in settings where TMDLs are to be done in phases, where a strong commitment to adaptive management exists, where issues are not highly controversial, and where stakeholders will take effective action for implementation. This is the case with the implementation and review/revision programs for Heavenly Valley Creek, which are discussed in Sections 5 and 6 below**.**

The applicable water quality standards for the Heavenly Valley Creek TMDL are instream aquatic life uses, and water quality objectives for sediment, suspended sediment, and settleable materials. The TMDL interprets these standards through multiple instream and hillslope indicators and numeric targets, with the baseline assumptions that:

- Some degree of water quality degradation and beneficial use impairment occurred due to ski resort development in the watershed before the adoption of the statewide Nondegradation Policy in 1968 and Regional Board adoption of water quality standards for the creek in 1975. This assumption is supported by the evidence summarized in Section 3.1.B, above.

- There is some amount of instream sediment loading <u>above</u> reference conditions under which beneficial uses will be supported and narrative water quality objectives met. This assumption is reasonable because of the inherent natural annual and seasonal variability of instream sediment levels, the uncertainty involved in modeling, and the variability of estimated "natural" suspended sediment concentrations and yields in undisturbed watersheds in the Lake Tahoe Basin. The assumption is also supported by LTBMU staff's "best professional judgement" conclusion (TRPA, 1995) that Heavenly Valley Creek will be adequately protected if hillslope sediment delivery is reduced to 335 tons per year.

These baseline assumptions are important because it may not be feasible to return the watershed to completely natural sediment yield conditions (at least on a human rather than a geologic time scale). The LTBMU model indicates that a 76% reduction in the 1995 hillslope sediment delivery level is the maximum feasible reduction which can be expected with full application of BMPs to roads, ski runs, and new development. (Some additional reduction in sediment delivery, and thus in instream sediment loading, may be possible from other planned restoration work at the ski resort, but this reduction has not been quantified for the Heavenly Valley Creek watershed. See Section 5.1.C, below.) Since "baseline" conditions for interpretation of standards reflect historic degradation, restoration of the creek to the presumably "pristine" conditions existing before ski resort development is not required as long as beneficial uses are adequately supported. The Heavenly Valley Creek TMDL focuses on maximizing beneficial use support to the extent practicable. The loading capacity and numeric targets are based on expectations of "reasonable further progress", defined as reductions in instream suspended sediment loading, and improving trends in instream habitat characteristics.

The TMDL uses an "inferred linkage" (USEPA Region IX, 2000) based on comparison of local reference conditions (in Hidden Valley Creek) with existing conditions in Heavenly Valley Creek. The conservative assumption is made that aquatic life uses will be adequately supported (and narrative water quality objectives will be met) when the total annual sediment loads in Heavenly Valley Creek are comparable to those in the reference stream, Hidden Valley Creek . The watershed of the monitored segment of Hidden Valley Creek is about 87 % of the size of Heavenly Valley Creek's watershed (1162 acres compared to 1341 acres). If Hidden Valley Creek's calculated sediment load were increased by 13%, the corresponding "target" level for Heavenly Valley Creek would be about 51 tons per year. The proposed TMDL target, 53 tons of sediment per year, expressed as a 5 year rolling average, reflects the assumption that BMPs will be 65 percent efficient when fully implemented. It appears to be reasonably comparable to reference conditions adjusted for differences in watershed size. The target is assumed to be substantially below the sediment load in Heavenly Valley Creek at the time standards became effective. It also represents a value believed to support beneficial uses in the creek.

Protection of beneficial uses of Heavenly Valley Creek related to fish habitat can be evaluated in relation to the Lahontan cutthroat trout, the original and only native trout species. A literature review indicates that the creek provides potentially good habitat for adult fish, but would be marginal rearing habitat even under natural conditions. This is due to the fact that the stream is very steep and in an area with high snowfall, and that Lahontan cutthroat trout spawn in spring when the early life stages are susceptible to the impacts of high snowmelt runoff.

In general early life stages (egg through the swim up stage) are the most susceptible to effects of sediment (Newcombe and MacDonald, 1991) The emergence of trout from redds can be reduce or entirely precluded if high amounts (greater than 25% by volume) of fine sediment are allowed to accumulate in redds. High concentrations of fine sediment diminish the dissolved oxygen concentrations by limiting circulation of well oxygenated water (McBrayer and Ringo, 1975). Fine sediment can also act to cement larger grains together creating a physical barrier to trout escaping from the gravel of the redd. High stream flows can mobilize gravel. Eggs incubating at these times are susceptible to physical injury or death from the grinding effects of gravel bed movement. Large amounts of snow that effectively constrain the channel and prevent water from spilling over the banks serve to accelerate stream flow and increase potential injury to incubating eggs (Erman *et al*.,1988).

No particle size analyses for Heavenly Valley Creek were available during development of this TMDL. However, because of the steepness of the watershed, Heavenly Valley Creek would probably tend to a coarse grain size distribution. High flows would tend to move very fine sediments downstream and out of the reach of concern. These high velocities could also regularly disturb spawning beds (Kondolf *et al*., 1991)

Newcombe and MacDonald (1991) reviewed the literature and evaluated suspended sediment concentration and “sediment intensity” as predictors of adverse effects on trout. They list some adverse effects at concentrations historically monitored in Heavenly Valley Creek. However, they have demonstrated that sediment concentration alone is not a good indicator of the severity of effects on trout. They argue for the use of a stress index based on concentration and duration of exposure as a more effective predictor of impacts.

The total sediment target for this TMDL is designed to capture the cumulative effects of sediment on fish and is set at a level believed to provide adequate habitat conditions for *adult* trout. The amount of spawning habitat within the reach is naturally limited (due to steepness and snow induced scour). It is unlikely that spawning habitat can be markedly increased within the listed reach. The existing habitat can be improved somewhat, but a greater improvement for the stream as a whole will occur if adults using this reach and spawning in lower reaches are provided excellent habitat. Improved habitat for adult fish will improve overall fitness of adults and result in improved egg quality. This should result in a net increase in survivorship.

The effects of sediment on adult fish are subtle. Behavioral changes and feeding patterns can be altered in situations of high suspended sediments. The load allocations established by this TMDL should result in suspended sediment concentrations significantly below 100 mg/l, given the flow regime evaluated. For example, the 1999 Property Line station showed only 2 samples above 56 mg/l suspended sediment and the total load for this year was estimated to be just over 53 tons. Newcombe and MacDonald reported few instances from the literature where suspended sediment concentrations at the 50 mg/l to 100 mg/l level showed significant impacts on juvenile or adult fish. The most pronounced impact not associated with early life stages seems to be a reduction in growth. The duration of the exposure to the highest anticipated concentrations will contribute to any potential impact. In Heavenly Valley Creek, the highest concentrations can be expected during approximately 6 weeks from the middle of May to the end of June. Given the expected improvements in stream habitat, any growth reduction associated with this level of exposure to suspended sediment will not compromise adult trout, and therefore the TMDL can be considered protective.

Long term evaluation of benthic invertebrate community metrics in Heavenly Valley Creek in comparison to those measured in other reference streams in the central Sierra Nevada will be needed to establish baseline levels and detect improving trends in benthic habitat uses. Data from Hidden Valley Creek will be used to capture the natural variations in stream flow and sediment loading. If adjustments in the loading capacity and/or load allocations for Heavenly Valley Creek are necessary in the future (e.g., due to large sedimentation events), data from Hidden Valley Creek can be used to define the proportional adjustments.

Section 3.5. TMDL and Load Allocations

TMDLs are the sum of “wasteload allocations” for point sources, “load allocations” for nonpoint sources, and an explicit or implicit “margin of safety”. Because the modeled sediment loading to Heavenly Valley Creek is entirely from nonpoint sources, and no point source discharges are expected to be proposed in the future, the wasteload allocation is zero. The margin of safety, which is implicit, is discussed in Section 3.6 below.

The "loading capacity" for Heavenly Valley Creek is total annual instream sediment load of 53 tons measured as a 5 year rolling average. The loading capacity reflects the assumption that implementation of BMPs will, over time lead to a 65 percent reduction in the modeled "total impaired discharge" of 150 tons/year. Table 13 summarizes the proposed allocation of the mitigated instream sediment loading among all source categories. Allocations are in English rather than metric tons, are rounded to the nearest ton, and do not distinguish between sources in California and Nevada. The proposed load allocations reflect assumptions in the LTBMU model about the efficiency of Best Management Practices, and USFS modeling results which predict reductions in sediment yield from specific areas after application of BMPs. No reduction in modeled "background" sediment delivery from undisturbed lands is assumed.

The LTBMU model was used in the Heavenly Resort Master Plan EIS (TRPA, 1995, 1996) to identify specific remedial erosion controls for past watershed disturbance to be implemented in coordination with permitting of new ski area development. The modeled mitigation targets *in the EIS* assumed that full BMPs would <u>not</u> be applied to some disturbed areas. Since completion of the EIS, the LTBMU has decided to require application of BMPs to *all* disturbed areas (Sherry Hazelhurst, personal communication). Regional Board staff calculated the final hillslope load reductions by applying the BMP efficiencies used in the LTBMU model to the "unmitigated" sediment yields predicted in the EIS, and adding the reduced yields to yields predicted from "mitigated" categories. For example, the EIS predicted 63 tons/year sediment yield from mitigated roads, and 30 tons/year from unmitigated roads. The LTBMU assumed that BMPs applied to both roads and ski runs were 80% efficient in controlling sediment (except for roads which would be abandoned and restored, where 90% efficiency was assumed). After application of BMPs, sediment yield from the former "unmitigated" road category would be (0.20)(30 tons/year) = 6 tons per year. Addition of this figure to the 63 tons/year for the former "mitigated" road category gives a mitigated hillslope sediment delivery rate for roads of 69 tons/year.

The load allocations for instream sediment were calculated by reducing the estimated total existing instream load from each source category (Table 9) by a percentage equivalent to the projected reduction in hillslope sediment delivery for that category after full application of BMPs (Table 12). A load allocation for sediment loading from new development was added, as explained in the next paragraph. Load allocations are summarized in Table 13, below.

Table 12. Modeled Maximum Feasible Reductions in Hillslope Sediment Delivery with Full Application of BMPs.

Source Category	**Reduced Load (tons/year)**	**Percent of Total**
Roads	69	53
Ski Runs	27	21
Undisturbed Lands	34	26
Impervious Surface*	0	0
TOTAL	**53**	**100%**

*The contribution of impervious surface to sediment loading is considered *de minimis.* See the text.

Proposed new development in the Heavenly Valley Creek watershed (TRPA 1995, 1996) includes four new ski lifts, a "Top Station" for the new resort gondola (most gondola facilities are in another watershed), four new ski runs, 3600 feet of new road, replacement of an existing lodge, and a relocated maintenance building. (Portions of two ski runs and the maintenance building will be located on the Nevada side of the watershed.) LTBMU modeling results indicate that soil loss to the stream would be increased by 0.741 tons per year due to proposed new development (after application of full BMPs).

Table 13. Instream Load Allocations for Total Sediment in Heavenly Valley Creek

Source Category	**Load Allocation (tons/year as a 5 year rolling average)**	**Percent of Total**
Roads	28	53
Ski Runs	11	21
New Development	0.7	*
Undisturbed lands	14	26
Impervious surface*	0	0
TOTAL	53.7**	100%**

*The contribution of impervious surface to sediment loading is considered *de minimis.* See the text.
** The discrepancy between the total load allocations and the loading capacity (53 tons/year) is considered to be within the margin of error of the calculations.

Section 3.6. Margin of Safety, Seasonal Variations, and Critical Conditions

A. Margin of Safety

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in determining the relationship between discharges of pollutants and impacts on water quality. An explicit MOS can be provided by reserving (not allocating) part of the total loading capacity, and therefore requiring greater load reductions from existing and/or future source categories. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The Heavenly Valley Creek TMDL includes an implicit margin of safety. An explicit MOS was not included because the load allocations assume that full application of BMPs will provide the maximum feasible load reduction, and therefore further significant reductions in hillslope sediment delivery cannot realistically be expected.

Sources of uncertainty in the Heavenly Valley Creek analysis include: (1) uncertainty related to interpretation of the narrative objectives; (2) the limited amount of data currently available for some parameters, such as bedload sediment and aquatic life use support; (3) the limitations of the LTBMU model; and (4) the inherent seasonal and annual variability in sediment delivery and instream impacts of sediment common to all stream systems. Limitations of the model (discussed in TRPA, 1995) include the inability of a standard model to account for all of the temporal and spatial variability in sediment delivery in a unique natural ecosystem (and especially inability to predict interaction among the various elements of the model), the use of simplifying assumptions (e.g., about the efficiency of BMPs), and the fact that the model has not yet been calibrated. In comments on earlier drafts of the Basin Plan amendments and staff report, the scientific peer reviewer (Kondolf, 1999) criticized the LTBMU model because of the lack of calibration, and the use of best professional judgement, and pointed out that it overestimated sediment yield when compared to the results of calculations using actual suspended sediment measurements.

As currently proposed, the Heavenly Valley Creek TMDL provides an implicit margin of safety by:

<u>1) Interpreting compliance with standards through use of multiple, dynamic targets and indicators.</u>

The TMDL uses a range of indicators and target values, including both instream and hillslope indicators to measure compliance with standards and to account for areas where data are scarce (e.g. bedload sediment loads and impacts). The hillslope targets supplement the instream targets and provide goals more directly associated with management activities in the watershed. The expression of the sediment delivery and suspended sediment targets as 5 year rolling averages accounts for the inherent variability in annual sediment delivery rates.

<u>2. Incorporating conservative assumptions in the source analysis and development of load allocations.</u>

An "inferred linkage" between conditions in Heavenly Valley Creek and Hidden Valley Creek was used to develop the loading capacity and load allocations (See Section 3.4 above.) Hidden Valley Creek is assumed to represent "pristine" instream sediment loading conditions and the loading capacity is set close to those conditions. This provides an implicit margin of safety in the TMDL.

The source analysis and load allocations use a conservative assumption about the efficiency of BMPs (65 percent). Based on the load reductions and BMP efficiencies used in the LTBMU model, an maximum overall reduction of 76 percent in hillslope sediment delivery could be expected. The TMDL analysis further compensates for uncertainty in the model by basing load allocations on aggressive reductions in sediment delivery from all significant anthropogenic sources.

3) Incorporating a rigorous monitoring and review program and schedule which provide an ongoing mechanism to adjust the TMDL if, in the future the Regional Board finds that water quality objectives are not being met or that beneficial uses are not being protected.

Sections 5 and 6 of this staff report discuss the TMDL monitoring program and the Regional Board's planned schedule for review and revision of the TMDL. The adaptive management approach to implementation includes annual review of the program and monitoring data by an interagency technical advisory group; adjustment of management measures as appropriate; and comprehensive review and adjustments to the program every five years. In addition to TMDL monitoring for Heavenly Valley and Hidden Valley Creeks, monitoring of water quality and beneficial use support in downstream waters of the Upper Truckee/Trout Creek watershed will continue under the Lake Tahoe Interagency Monitoring Program and the Regional Board's Watershed Management Initiative program.

B. Seasonal Variations and Critical Conditions

All stream ecosystems, whether or not they have been disturbed by human activities, exhibit seasonal and annual variations in the rate of sediment delivery to the stream and in the impacts of sediment on stream organisms during different stages of their life cycles. Sediment impacts may be more important if they affect "critical conditions" of an organism's life cycle than if they occur at other times; e.g., sedimentation of spawning gravels can have particularly significant effects on early developmental stages of fish. Furthermore, there may be significant temporal lags and spatial disconnects between hillslope erosion events and the impacts of sediment on instream uses.

The TMDL uses multiple numeric targets and indicators in order to integrate the net cumulative effects of sedimentation over longer time frames. A variety of hillslope and instream indicators are used, and together, they address the effects of sediment loading, transport, deposition, and impacts on beneficial uses. The loading capacity, and load allocations are expressed as 5 year rolling averages in order to account for natural seasonal and annual variation in sediment loads, with the recognition that trends may not be apparent within shorter time frames. Several numeric targets are also expressed as long term trends. The TMDL and load allocations are set at levels which, over time, will allow instream aquatic habitat to recover to a level which adequately supports aquatic life uses.

Section 4. Public Participation

Federal regulations include a minimum requirement that the public be allowed to review and comment on draft TMDLs. For TMDLs adopted as Basin Plan amendments in California, opportunities for public participation are provided through the amendment procedures summarized in the USEPA Region IX *Guidance for Developing TMDLs in California* (2000), and through the California Environmental Quality Act (CEQA) review process. The Regional Board maintains a large mailing list of parties interested in receiving draft Basin Plan amendments and/or hearing notices, and a separate large mailing list for agenda announcements. The Basin Plan amendment and CEQA review processes include opportunities for written public comments and testimony at a noticed public hearing. Written responses are required for written public comments received during the noticed public review period, and staff respond orally to late written comments and hearing testimony before the Regional Board considers adoption. The Lahontan Regional Board's Basin Plan amendments (including draft TMDLs) are now made available on the Internet and publicized through press releases. Further opportunities for public participation are also provided in connection with review and approval of Regional Board-approved Basin Plan amendments by the SWRCB and the USEPA. Documentation of public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony, will be included in the administrative record of the Basin Plan amendments for USEPA review.

Section 5. Implementation and Monitoring

Section 5.1 Implementation Actions and Management Measures

A. Erosion Controls for Existing Disturbance

Implementation of the TMDL is the responsibility of the U.S. Forest Service, Lake Tahoe Basin Management Unit and the Heavenly Ski Resort. It involves continuation of the erosion control and monitoring programs which were agreed upon as mitigation for the 1996 Heavenly Master Plan, and which have been implemented for the ski resort as a whole since 1997, with addition of biomonitoring.

Implementation includes application of Best Management Practices to all disturbed areas in the watershed (Sherry Hazelhurst, USFS, personal communication). The following is a summary of the erosion controls planned for specific source categories. The management measures listed were those assumed in inputs to the LTBMU model; through the adaptive management approach, other measures may also be applied. Mechanical or vegetative BMPs which may be used as part of the remedial erosion control program include, but are not limited to: retaining structures at the foot of overly steep slopes, riprap, surface roughening, interception trenches or water bars, revegetation, and ground covers such as straw, bark or pine needle mulch.

1. Abandonment and restoration of 7.59 acres of existing unpaved roads which are not essential for ski resort operations. An overall assumption of 90 percent efficiency in reducing sediment delivery was made for this component of the implementation program. The model assumed use of the following management practices:

a. Use of water bars

b. Revegetation of the road and cut and fill banks with grass and/or shrubs. This was expected to increase Percent Canopy, Percent Ground Cover, and Percent Fine Roots to 35 percent. Where the slope is too steep for successful revegetation, it may be reshaped to reduce the slope or some other permanent stabilization measure may be used.

c. Increase road surface roughness through tracking or scarring. This was predicted to decrease the "available water" (R-Value) factor in the Modified Universal Soil Loss Equation from 4 to 2, and to increase the Surface Roughness from 0.25 to 2.0.

d. Cover embankments with mulch or straw, also increasing the Surface Roughness from 0.25 to 2.0.

2. Restoration of the 21.10 remaining acres of existing unpaved roads which are not planned for abandonment. The model input assumed the following mitigation measures:

a. Use water bars

b. Revegetate the road cut and fill banks with grass and/or shrubs in order to increase Percent Ground Cover and Percent Fine Roots factors to 25 percent. When the slope is too steep for successful revegetation, some permanent stabilization (e.g., rock retaining wall) will also be employed. (The modeling results show percent cover increases for specific road segments from 35-70%.)

c. Cover embankments with mulch or straw to increase the Surface Roughness Factor from 0.25 to 2.0 and increase Percent Cover to 20.

3. Restoration of 182 acres of existing ski runs. The model assumed implementation of the following mitigation measures, with an overall efficiency of 80 percent in reducing sediment delivery:

a. Use water bars.

b. Revegetate runs with grass and/or shrubs. The model assumed that revegetation would result in a maximum ground cover of 70 percent and percent fine roots one third of the percent cover. Vegetation increases surface roughness, and increases the model

Roughness variable by 1 (e.g., from 2 to 3). If necessary, revegetation will include stabilization techniques such as use of tackifiers or erosion control blankets or netting. The vegetation will be maintained with water and fertilizer until it has been established and can survive on its own. If monitoring shows that revegetation efforts have failed in certain areas, they will be revegetated again, or more appropriate stabilization measures will be used.

c. Mulch or straw cover the embankments.

The LTBMU model identifies specific needs for BMPs to be applied to each existing road and ski run segment. The modeling results (see example in Appendix 1) summarize, for each ski run or road segment, the reason for mitigation, the percent slope before and after mitigation, the number of water bars, presence of mulch or straw cover, existing and mitigated percent cover (vegetation, duff, etc.), soil loss and Equivalent Roaded Area before and after mitigation, and the year in which mitigation will take place.

The remedial program also includes continuation under USFS oversight of erosion control projects designed by the U.S. Natural Resources Conservation Service before the watershed-wide needs survey using the LTBMU model.

The remedial erosion control program is an adaptive management program. LTBMU staff monitor a variety of parameters, including BMP effectiveness (see the discussion of monitoring, below) and evaluate monitoring results annually. Annual monitoring reports include site specific recommendations regarding management practices. If needed, adjustments in management measures for specific sites are made the following year. The mitigation program also includes provisions for restoration or repair of critical areas damaged by natural disasters. More comprehensive evaluations of the success of the remedial program are scheduled to occur every five years. The first five year evaluation is being done in 2000, and the LTBMU has convened an interagency Technical Advisory Committee, including Regional Board staff, to assist in the process.

B. Erosion Controls for New Construction

The ski resort master plan also requires full implementation of temporary and permanent BMPs for control of erosion and stormwater runoff for all new construction. The need for special management practices in connection with ski resort development in the Lake Tahoe Basin has been recognized since the 1970s (California Tahoe Regional Planning Agency, 1977). The Heavenly Ski Resort Master Plan EIS (TRPA 1995, 1996) identifies BMPs which might potentially be used in a variety of construction situations. For new ski runs, snowmaking pipelines will be placed above ground, and consequently will not increase soil erosion. The pipelines will be used for irrigation, which will increase the chance of success for any revegetation on the new runs. (Current construction practices for ski runs involve cutting trees but leaving other native vegetation, rocks, duff, etc. in place. Full revegetation may not be required for new runs.)

Project-specific BMPs will be identified in connection with environmental review and permitting for all new construction. The mitigation program includes formal inspections at the start of construction, at least twice per month during construction, and during and at the end of storm events. The program directs inspectors to require correction of inadequate BMPs whenever detected during other site visits. If BMPs are judged to be inadequate, construction must be halted until they are in place. The scheduling of restoration projects will be coordinated with that for new resort facilities so that restored areas will not be disturbed again.

C. Additional Watershed Mitigation

The TMDL implementation program consists of the erosion control measures outlined above and the monitoring program described below. Estimated sediment delivery reductions from these measures were used in development of numeric targets and load allocations. However, a number of other watershed restoration activities are currently planned in the Heavenly Valley Creek watershed under the Heavenly Ski Resort Master Plan, other LTBMU authority, and the Tahoe Regional Planning Agency's "Environmental Improvement Program" (TRPA, 1998). The reasonable certainty that these projects will be implemented adds to the implicit margin of safety for the TMDL.

Under the Heavenly Ski Resort Master Plan, mitigation will be required for new and existing impervious surface in the watershed. Potential mitigation measures include full stabilization and revegetation of the ground surfaces around the impervious surface, and use of infiltration trenches or other BMPs to minimize increased runoff.

Also under the Master Plan, 11 acres of disturbed Stream Environment Zone will be restored in the Heavenly Valley Creek watershed. Properly functioning SEZs act as filters to remove suspended sediment from surface runoff, and increased functional SEZ area will add to the modeled reductions in hillslope sediment loading. Additional specific SEZ mitigation may be identified during review of individual Master Plan projects. For example, CEQA/NEPA mitigation measures for the recently approved construction of a ski lodge and expanded snowmaking equipment in the Sky Meadows area of the Heavenly Valley Creek watershed include relocation of some existing facilities outside of the SEZ and the restoration of about 600 square feet of disturbed SEZ within Sky Meadows (U.S. Forest Service, 1998).

Between 1995 and 1998, the LTBMU evaluated all structures at the Heavenly ski resort (ski lifts, lodges, restrooms, snowmaking facilities, maintenance facilities, etc.) and identified specific needs for retrofitting of Best Management Practices. (Retrofit of BMPs to all existing development in the Lake Tahoe Basin is required by state and TRPA water quality plans; see Chapter 5 of the Lahontan Basin Plan.) Prioritized recommendations for retrofit are summarized in Hazelhurst *et al*. (1999). Potential BMPs include infiltration and runoff control systems, and revegetation and mulch of areas adjacent to structures to improve infiltration and prevent accelerated erosion. Retrofit will be included in summer restoration work based on priorities and master plan phasing. The potential reduction in sediment delivery to Heavenly Valley Creek from implementation of these BMPs has not been quantified or included in the TMDL. However, BMP retrofit should cumulatively (with remedial erosion control work for ski runs and roads) contribute to reduced sediment delivery, and attainment of instream standards.

The TRPA's Environmental Improvement Program (EIP) is a part of that agency's regional land use plan (which also incorporates the Heavenly Ski Resort Master Plan). The EIP identifies specific projects which TRPA believes must be implemented in order to attain regional environmental standards. It includes a two phase fish habitat restoration project for Heavenly Valley Creek. The first phase (EIP Project 404), to be implemented in 2004 at a cost of $50,000, would stabilize the banks of a 1 mile segment of the creek downstream of the ski resort through revegetation, raising the overall habitat rating of the creek from "marginal" to good. The second phase (EIP Project 710), which would address the segment of the creek affected by the TMDL, would be completed in 2007 at a cost of $500,000. It would improve stream channel morphology "as needed", including development of pools, improvement of bed substrate, and removal of barriers to fish passage created by roads and culverts. The project would also include facilitation of a water rights exchange to replace the stream diversion for snowmaking with another water source. The Phase II project is expected to raise the fish habitat rating of the entire stream from "good" to "excellent". Funding for the EIP has not yet been assured, but TRPA is actively seeking funds from Congress and other sources for the entire $900 million program.

The proposed instream improvements through the EIP will complement the hillslope sediment controls in the Heavenly Valley Creek watershed, which should be completed at about the same time. Together, these controls will help to ensure attainment of the narrative water quality objectives related to sediment.

Section 5.2 Schedules for Implementation and Attainment

A. Schedule for Implementation

The TMDL implementation program relies on continuation of the USFS erosion control and monitoring programs for the Heavenly ski resort, which are already being implemented under the Master Plan schedule discussed below. The Basin Plan amendments will include recommended schedules for implementation and monitoring, with recognition that these may be changed through the adaptive management program which includes consultation with Regional Board staff.

As explained in the *Heavenly 1998 Master Plan Projects CWE Compliance Report* (U.S. Forest Service, 1998), the master plan EIS included a 10-year schedule for restoration of ski run and road segments. The schedule included specific ski run and road segments to be restored in each of the 10 years after approval of the master plan and EIS. The scheduled also included flexibility for revision in coordination with specific development projects provided that 1) the scheduled total acreage for each year (for the ski resort as a whole) is restored; 2) the total scheduled reduction in Equivalent Roaded Acres is achieved each year (for the ski resort as a whole) and 3) within each watershed, there is a downward trend in each year. "Existing" conditions for evaluation of implementation were based on the 1991 LTBMU field measurements; however, the Master Plan EIS allowed Heavenly credit for restoration work performed between 1991 and 1996. In 1997, the LTBMU and the Heavenly ski resort developed a schedule for coordination of restoration work with development projects through 2000, which a NEPA analysis concluded was environmentally equivalent to compliance with the original Master Plan restoration schedule. According to the *Compliance Report*, over three times the originally scheduled acreage was restored in the Heavenly Valley Creek watershed in 1997. (Actual restoration included 34.82 acres of ski runs and 4.45 acres of roads.) Restoration work to be completed in 1998 alone was expected to reduce ultimate total soil delivery to Heavenly Valley Creek by 159.9 tons/year. Figures for the total cumulative reduction in long term sediment delivery to date (1991-2000) are not currently available. They will probably be included in the LTBMU five-year evaluation report which is due to be released in early 2001.

The 10 year schedule for implementation for the remedial erosion control program involves mitigating the most severe erosion sources first and progressing to the least severe. The most severe problems are to be addressed during the first seven years (1997-2003); the remainder of the remedial work is scheduled for Years 8-10 (2004-2006). As noted in Section 5.1.C above, the TRPA Environmental Improvement Program fish habitat restoration project for Heavenly Valley Creek (TRPA, 1998) is also scheduled to be completed by 2007.

Progress toward implementation will be evaluated through the adaptive management approach, including annual evaluations and adjustments of management practices, and more comprehensive reviews once every five years. Because the work scheduled for the second five years will produce relatively little reduction in erosion compared to the earlier work, implementation plans will be re-evaluated at the five -year point to determine if they still represent the best plan for reducing erosion. If not, a modified program will be developed and implemented.

B. Schedule for Attainment

The remedial erosion control program (installation of BMPs) is expected to be complete by 2006. However, recovery of the watershed and the stream ecosystem to the point where narrative water quality objectives are attained and instream beneficial uses are supported at a satisfactory level will probably be a decades-long process. As noted above, there can be significant spatial and temporal lags between erosion events and sediment delivery to streams, and between sediment delivery and sediment impacts on beneficial uses. Even after stabilization of the watershed, time will be required for flushing of existing excess sediment from Heavenly Valley Creek, and for recovery of instream aquatic life uses. As long as the current hydromodification of Heavenly Valley Creek (the reservoir and culverted section of stream) remains in place, recovery of the stream as a whole to "pristine" conditions cannot be expected. However, this TMDL analysis predicts recovery of benthic communities to conditions which attain standards (interpreted in terms of degraded "baseline conditions" as discussed in Section 3.1.C. above) within 20 years after the effective date of the TMDL (by 2021). This prediction is supported by modeling and monitoring results for the Heavenly ski resort which indicate that hillslope stability can be achieved within that time frame, and scientific literature which shows that disturbed benthic communities can recover quickly if suitable habitat is restored.

The LTBMU model predicts that disturbed acreage in the watershed, and the potential for sediment yield, will be significantly reduced after the first ten years. These expectations reflect the fact that many soil erosion BMPs (e.g., water bars, reduction of cutbank slopes, rock-lined drainage ditches, and graveling of roads) are effective immediately upon installation. Although revegetation must be fully established to be completely effective, even sparse vegetation provides some benefit during the interim period. Mulch of revegetated areas also provides interim erosion control.

Percent cover on ski runs for the ski resort as a whole has increased significantly since the first measurements in 1991. For the given subsample of ski runs, percent cover is now between "good" and "excellent", indicating attainment of the proposed target (Hazelhurst *et al.*, 1999). The results for the ski area as a whole cannot necessarily be extrapolated to the Heavenly Valley Creek watershed, but they indicate that there is a reasonably good chance of attainment of hillslope targets, which will eventually lead to attainment of instream standards.

The scientific literature (e.g., Hawkins *et al.* 1994) indicates that benthic invertebrate communities in streams can recover fairly rapidly following catastrophic disturbances such as volcanic eruptions, assuming that physical instream habitat conditions have recovered. In the Clearwater Basin near Mt. St. Helens, invertebrates in tributary streams recovered rapidly after scouring of sediment that revealed pre-1980 eruption substrate, and population densities were similar to those under reference conditions within two years. In Clearwater Creek, sculpin populations recovered to densities as high or higher than pre-eruption levels by 1985. Trout populations were only 20 % of previous levels in 1990, which was attributed to lack of spawning habitat; but trout condition was good due to rapid recovery of invertebrate prey (Hawkins *et al.*, 1994).

Section 5.3. "Reasonable Assurance" of Implementation

The USEPA's guidance for the development of TMDLs (1999, 2000) directs states to provide "reasonable assurance" that implementation activities will occur. The USEPA Region IX (USEPA, 2000) guidance cites a 1997 national policy

> *"that all TMDLs are expected to provide reasonable assurances that they can and will be implemented in a manner that results in attainment of water quality standards. This means that the wasteload and load allocations are technically feasible and reasonably assured of being implemented in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate".*

The sediment protocol document (USEPA, 1999) summarizes the direction in the draft revisions to the Section 303(d) regulations to the effect that:

> *"Reasonable assurance means a high degree of confidence that the wasteload allocations and or load allocations in TMDLs will be implemented by Federal, State or local authorities and/or voluntary action... . For nonpoint sources , reasonable assurance means that nonpoint source controls are specific to the pollutant of concern, implemented according to an expeditious schedule, and supported by reliable delivery mechanism and adequate funding".*

The Heavenly Valley Creek TMDL implementation program incorporates an erosion control program which is already in the fifth year of a ten-year implementation schedule. Lahontan Regional Board staff have a high degree of confidence that it will be completed on schedule. (See the discussion of authority for implementation, below.) The management practices outlined above are specific to sediment control, and have been used widely enough in the Lake Tahoe Basin and similar environments to provide confidence in their technical feasibility. The erosion control and monitoring programs are being funded by the Heavenly ski resort, which has adequate financial resources to ensure that erosion control work will be done on schedule and that monitoring will continue indefinitely.

Although there is ample regulatory authority to ensure implementation of the TMDL, there is also a high degree of stakeholder commitment to work for watershed restoration in the Lake Tahoe Basin as a whole. The Heavenly Valley Creek remedial program was designed and is being implemented in the context of the very comprehensive existing water quality control program for the entire Lake Tahoe watershed, which is summarized in Chapter 5 of the Basin Plan. Elements of the program relevant to control of sediment in the Heavenly Valley Creek watershed include: general and specific prohibitions against discharges or threatened discharges of sediment; limitations on impervious surface coverage; stormwater effluent limitations; mandatory implementation of temporary and permanent BMPs; protection of Stream Environment Zones and 100 year flood plains; and limitations on types of ski area facilities which can be constructed on high erosion hazard lands. The proposed TMDL is consistent with and will implement the water quality standards and control measures in Chapter 5 of the Basin Plan. The remedial work at Heavenly also falls within a larger interagency "Watershed Management Initiative" for the Trout Creek/Upper Truckee River watershed as a whole.

The regulatory authorities and stakeholder commitments which will affect the implementation of the TMDLs are described below and summarized in Table 14.

Lahontan Regional Board. The Regional Board has regulatory authority to enforce implementation of the TMDL under both the Clean Water Act and the California Water Code. The TMDL numerical targets themselves are not enforceable, except for those set at the level of water quality standards. Under Section 13360 of the California Water Code Regional Boards cannot specify the design, location, type of construction or particular manner of compliance with Board orders. The Board does have the authority to adopt waste discharge requirements, and/or a stormwater NPDES permit, to ensure compliance with water quality standards in Heavenly Valley Creek. The Board, or its Executive Officer may also require water quality monitoring programs which specify monitoring of specific parameters, separately from water quality permits (Water Code Section 13267). The Board's enforcement authority is summarized in Chapter 4 of the Basin Plan.

Initially, Regional Board staff intend to pursue implementation of the Heavenly Valley Creek TMDLs under the "three-tier" approach of the revised statewide nonpoint source control plan (California State Water Resources Control Board, 2000), and to treat the erosion control and monitoring programs as "self-determined implementation". Regional Board staff will continue to participate in the interagency technical advisory group which carries out annual and five year reviews of the Heavenly ski resort erosion control and monitoring programs. Regional Board staff will maintain oversight of maintenance activities at Heavenly through the existing waste discharge requirements and monitoring program (Board Order 6-91-36) and, under the three-tier approach, may request the Board to consider revising this order to include the TMDLs in the future. (The permit is scheduled for its next update in 2001.) The Regional Board will continue to act as a responsible agency under CEQA for new ski resort development projects as they are approved.

U.S. Forest Service. The LTBMU's *Land and Resource Management Plan* has water quality protection as its primary goal. In 1996, the LTBMU amended this plan to add commitments for implementation and monitoring of erosion controls to the "Management Area Standards and Guidelines" and "Proposed Resolution of Issues and Concerns" for the Heavenly Management Area. As part of the USFS Pacific Southwest Region (PSW), the LTBMU is also committed to ensure implementation of BMPs through a statewide Management Agency Agreement between the State Water Resources Control Board and the PSW. Through its permit for the Heavenly ski resort, the Forest Service has authority to ensure implementation of the erosion control and monitoring programs in both California and Nevada. These programs were required as mitigation for the Heavenly Ski Resort Master Plan under the National Environmental Policy Act (NEPA). The Master Plan allows the USFS to disapprove proposed new ski resort development if satisfactory progress is not being made on the remedial erosion control work.

The LTBMU is also committed to watershed restoration at Lake Tahoe as a partner in the Regional Board's Watershed Management Initiative for the Upper Truckee River/Trout Creek watershed (including Heavenly Valley Creek), and as the lead agency for the "Presidential Deliverables" program which resulted from President Clinton's visit to Lake Tahoe in 1997.

Tahoe Regional Planning Agency. The TRPA has been charged by Congress (under P.L. 96-551) to ensure attainment of the most stringent state and federal water quality standards within its jurisdiction. The TRPA has a *Water Quality Management Plan for the Lake Tahoe Region,* adopted under Section 208 of the Clean Water Act and approved by California, Nevada, and the U.S. Environmental Protection Agency. The Heavenly Ski Resort Master Plan, which includes the erosion control and monitoring programs incorporated into the TMDL implementation program, has been incorporated into TRPA's regional land use plan. (TRPA also approved the erosion control and monitoring programs as mitigation under its P. L. 96-551 environmental review process, which is legally separate from the CEQA and NEPA processes.) TRPA's land use and "Section 208" plans incorporate land use prohibitions (against 100 year flood plain SEZ disturbance, etc.) similar to the waste discharge prohibitions in the Regional Board's Basin Plan amendments, and require retrofit of BMPs for all existing development. Although TRPA's enforcement authority is not as comprehensive as the Lahontan Regional Board's, it does have authority to ensure implementation of the erosion control and monitoring programs in both the California and Nevada sides of the Heavenly Valley Creek watershed.

Section 5.4. Monitoring Plan

Monitoring of the success of watershed restoration efforts at Heavenly has been ongoing for many years to meet USFS and Regional Board requirements. The monitoring program approved under the Master Plan EIS is also a part of the mitigation monitoring program required under the California Environmental Quality Act (Public Resources Code Section 21081.6). The USFS currently monitors the following parameters for the ski resort as a whole:

- Water quality (specific conductivity, turbidity, suspended sediment, total nitrate/nitrite, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate, chloride)

- Soil erosion, and effective soil cover for the ski area as a whole, using both fixed plots and 15 randomly selected ski runs, roads and undeveloped areas. Fixed plots have been established on 20 ski runs and 5 undeveloped sites for long term monitoring. Direct measurements of soil erosion will be obtained from erosion pins and troughs, and indirect measurements will be taken from actual soil cover components and a soil loss prediction model

- BMP effectiveness (temporary and permanent). Monitoring of vegetation will take place during the growing season

- Riparian and stream channel condition.

Hidden Valley Creek is also being monitored as a reference stream.

Table 15 summarizes the elements of the monitoring program needed to determine compliance with the Heavenly Valley Creek TMDL indicators and targets. With the exception of bioassessment of benthic macroinvertebrates, all of these elements are part of the ongoing USFS monitoring program. Regional Board staff recognize that sampling stations and frequencies may need to be changed over time as a result of the adaptive management approach to implementation. (BMP effectiveness is not proposed as a TMDL indicator, but it will continue to be monitored and used in evaluation of the success of restoration efforts.)

The following description of the bioassessment protocol proposed for addition to the monitoring program was provided by Thomas Suk of Regional Board staff.
The full protocol involves documenting physical habitat quality for benthic macroinvertebrates and sampling and identification of invertebrates from selected study reaches. Fieldwork includes mapping, permanent photo points and GPS data, and measurements of habitat characteristics such as current velocity, depth, width, substrate size, cobble embeddedness, bank stability, riparian cover, discharge, bank angles, slope, temperature, and sinuousity. (To the extent that physical habitat measurements are
Table 14. Authority for implementation of the Heavenly Valley Creek TMDL.

Agency	Authority/Commitment Related to Implementation
U.S. Forest Service, Lake Tahoe Basin Management Unit	• 1988 Land and Resource Management Plan • Pacific Southwest Region "Section 208" Plan and Management Agency Agreement (MAA) with State and Regional Boards, committing to implement BMPs • Partner in Upper Truckee River/Trout Creek WMI effort • Lead agency for Tahoe "Presidential deliverables" program
California Regional Water Quality Control Board, Lahontan Region and California State Water Resources Control Board.	• Clean Water Act • Porter Cologne Act • Nonpoint Source Plan (California State Water Resources Control Board, 2000) • Lahontan Basin Plan including Lake Tahoe Basin chapter • MAA with USFS, Pacific Southwest Region • Certification authority over TRPA "208 Plan" • Upper Truckee/Trout Creek is a "priority" Watershed Management Initiative (WMI) watershed
Tahoe Regional Planning Agency	• Congressionally enacted Tahoe Regional Planning Compact (PL 96-551) • Water Quality Management Plan for the Lake Tahoe Region ("Section 208 Plan) certified by CA, NV and USEPA • Regional Plan, incorporating Heavenly Ski Resort Master Plan and EIP • Partner in Upper Truckee River/Trout Creek WMI effort

similar to those already being measured in the LTBMU's stream channel condition assessment, it may be possible to eliminate duplicative measurements and reduce sampling costs.) Biological work includes collection, field processing, and preservation of stream invertebrate samples, and laboratory sorting, subsampling, and identification. Results are reported in terms of physical habitat quality and occurrence and density of aquatic macroinvertebrate taxa.

Biomonitoring stations for Heavenly Valley and Hidden Valley Creeks should be located at or near LTBMU monitoring stations for physical and chemical parameters. Numbers and locations of stations, and frequency of sampling will be determined in consultation with LTBMU and Heavenly staff. At least three to five stations should be sampled in Heavenly Valley Creek, and three to five in Hidden Valley Creek. Ideally, sampling should be conducted for two consecutive years to determine current conditions at the impacted and reference sites, and resampling should occur every two years thereafter to document trends.

The LTBMU produces annual monitoring reports, including management recommendations to improve standard practices. A technical advisory committee meets annually to review the data and discuss recommendations for implementation during the next field season. Monitoring results will also be used to develop recommendations to improve management practices over the longer term. A comprehensive report on the monitoring data is to be completed in 2000 to quantify conditions and trends compared to 1991 baseline conditions. Similar reviews will be done after 10 and 15 years of monitoring. The need for long term monitoring to document the success of erosion controls has been recognized, and the monitoring program is expected to continue indefinitely, although it may be modified over time to focus on the data which are most useful for ski area management and environmental protection.

Section 6 . Review and Revision of TMDL

Regional Board staff will continue to participate in the interagency technical advisory group convened by the U.S. Forest Service to review annual monitoring data. Staff will also participate in annual adaptive management planning, and in the comprehensive evaluations to be held at five year intervals. Regional Board staff will use the five-year reviews as vehicles for evaluation of progress toward attainment of load allocations and numeric targets. Because the load allocations are expressed as five year rolling averages, and other numeric targets are expressed as long term trends, the first decision point regarding needs for revision of the TMDL will probably occur after the second five-year review (in 2010). However, the University of California, Tahoe Research Group (TRG) is developing a separate, more sophisticated sediment/nutrient loading model for the Lake Tahoe watershed as a whole, which is expected to be used to develop TMDLs for Lake Tahoe. The TRG model will use different data and assumptions than the LTBMU model. If the results of the TRG model indicate that the LTBMU model significantly underestimated sediment loading to the Section 303(d)-listed segment of Heavenly Valley Creek, revision of the TMDL could be considered earlier. Revision could also be triggered earlier if calibration of the LTBMU model (planned for 2000-2001) leads to greatly different estimates of hillslope sediment delivery, if ongoing monitoring of erosion control work at Heavenly shows that the restoration program is <u>not</u> adequate to meet the hillslope targets, or if substantial new development (beyond the scope of the current master plan) is proposed in the watershed. The Lahontan Regional Board is now sponsoring biomonitoring of stream macroinvertebrates throughout the central Sierra Nevada with a view toward developing water quality objectives incorporating "biocriteria". The results of the biomonitoring studies should provide more specific grounds for interpreting aquatic life use support in Heavenly Valley Creek, and for revision of the TMDL if needed in the future.

Table 15. Summary of Recommended TMDL Monitoring Program

Indicator	Sampling Location (s)	Sampling Frequency
Suspended sediment concentration	Heavenly Valley Creek "Property Line" station and Hidden Valley Creek	Monthly, with more frequent samples during snowmelt runoff
Suspended sediment loading	Heavenly Valley Creek at "Property Line" station, and Hidden Valley Creek	Calculated annually based on concentration and flow measurements
Pfankuch channel stability index	Heavenly Valley and Hidden Valley Creeks	At least once every 5 years.
USFS Region 5 Stream Condition Index	Heavenly Valley and Hidden Valley Creeks	Full surveys at least once every 5 years; continued annual monitoring of stream cross sections on Heavenly Valley Creek
Benthic invertebrate community health	3-5 stations each on Heavenly Valley and Hidden Valley Creeks	Baseline sampling for 2 consecutive years; and every 2 years thereafter
Percent Equivalent Roaded Area.	Entire watershed	Estimated annually based on restoration work completed to date
Effective soil cover (vegetation, woody debris, organic matter, rocks) on ski runs and roads	Annual random samples of roads and ski runs throughout resort as a whole	Cover increases for resort as a whole estimated annually based on measurements for sampled roads and runs
BMP effectiveness	Annual randomly sampled roads and ski runs throughout resort as a whole	Annual inspections; damaged BMPs are repaired or supplemented on a site specific basis

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Appendix 1: Sediment Delivery Modeling for the Heavenly Valley Creek TMDL

The Section 303(d)-listed segment of Heavenly Valley Creek is a reach approximately 2.7 miles long which extends from the headwaters of the creek to the boundary of the U.S. Forest Service (USFS) permit area for the Heavenly ski resort. The watershed tributary to the listed segment has an area of 1341 acres. All of the modeling results discussed below refer to this portion of the watershed.

The sediment delivery model used in the Heavenly Valley Creek TMDL was developed by staff of the USFS Lake Tahoe Basin Management Unit (LTBMU) to identify watershed restoration needs under the Heavenly Ski Resort Master Plan (TRPA, 1995, 1996). The LTBMU based its model on several procedures described in the "WRENNS Handbook" (USFS, 1980) and the *Guide for Predicting Sediment Yields from Forested Watersheds* (USFS, 1981). The WRENNS Handbook is widely used by USFS resource managers to analyze the impacts of timber harvest activities on watersheds, and can be adapted to other types of land disturbance such as ski resort development. The *Guide for Predicting Sediment Yields* is based on extensive studies in the Idaho Batholith, an area with decomposed granitic soils similar to those in the Heavenly area. The LTBMU model (Holland, 1993; TRPA, 1995, 1996) applies the methodology from these two publications using field data collected at Heavenly in 1991 and 1995. Calibration of the model (based on subsequent monitoring data, including direct measurements of erosion) will occur during the winter of 2000-2001 (Sherry Hazelhurst, LTBMU, personal communication).

The USEPA's *Protocol for Developing Sediment TMDLs* (1999) states that the WRENNS methodology is a "mid-range" model (compared with simple and detailed methods), which is sensitive to changes in the driving forces that influence sedimentation. It represents a compromise between empirical and mechanistic models, and is reliable for order of magnitude accuracy. WRENNS is one of a group of models which segment watersheds into land types and land system inventories. Each land parcel in the watershed is allocated erosion hazard potential and sediment delivery ratio values that allow generation of erosion curves for each disturbance source on the watershed. The USEPA protocol document recommends that estimates of sediment delivery using WRENNS and similar models be based on field information collected for the specific purposes of the model; site-specific information has been used in the LTBMU model for Heavenly Valley Creek. The USEPA protocol also suggests that models such as WRENNS should be used with caution in cases where extreme watershed conditions predominate (e.g. very steep topography, landslide-dominated erosion, and radically variable precipitation regimes), and that other methods including the "Revised Universal Soil Loss Equation" or one of its variants might be preferable in mountainous regions. As explained below, the LTBMU model estimates sediment delivery using the "Modified Universal Soil Loss Equation" outlined in the WRENNS handbook, with adjustments for rill and gully erosion, and other modifications based on the Idaho batholith studies (USFS, 1981; Megahan and Kidd, 1972; Burroughs and King, 1989).

Model Results Used in TMDL Source Analysis

Sediment Delivery Estimation
The WRENSS Handbook includes a procedure for estimating soil loss which is an adaptation of the Universal Soil Loss Equation (USLE) for steeper forested lands. WRENNS also includes a method for estimating sediment delivery to a stream channel. The LTBMU model for Heavenly is numerically based on the Modified Universal Soil Loss Equation (MUSLE), used in conjunction with a sediment delivery ratio (Holland, 1993).

The following, from Holland (1993), is a summary of the types of data required for input into the WRENNS model, with notes on specific procedures used in the LTBMU model for the Heavenly ski resort. (Modeling results for the Heavenly Valley Creek watershed were based on field measurements of 266 road segments, 124 ski run segments, and 26 undeveloped or undisturbed segments..

"The WRENNS model requires the following data input to calculate sediment delivery (Tons/year):

1. Acres of Disturbance- Field surveys measured the width and length of ski run segments to obtain acreage estimates. Road prisms, cuts and fills were also measured likewise for each segment.

2. K-factor- This is the "soil erosivity " factor and represents the predominantly Cagwin/Toem soil association found in the Heavenly area. The K-factor is a reflection of the inherent properties of the soil that relate to erodibility. The K-factor currently used in the model is constant although further soils evaluation should provide enough information to vary the factor according to soil type.

3. Precipitation- This number represents the average rainfall over the ski area for a two year, six hour event. The number is taken from a precipitation map prepared by NOAA[the National Oceanographic and Atmospheric Administration.].This number is used to calculate the R-factor, a component in the MSLE [sic] for determining soil erosion (in Tons/Acre/Yr). The rainfall currently used in the model is constant for all areas on Heavenly. Further monitoring may indicate variable rainfall patterns in the Heavenly area and if this is determined then variable rainfall factors will be used in the model.

4. Slope gradient- The slope gradient is the vertical elevation difference between the lower boundary of a sediment source area and the stream channel divided by the horizontal distance. It reflects the slope over which sediment travels to reach a channel. For roads, the slope gradient is the cut and fill slope. This is the average slope gradient expressed as percentage slope. This and slope length are the two most important factors in the soil erosion estimate.

5. Slope length- this is the distance from the point of origin of overland flow to:

   a. the point where the slope decreases to the extent that deposition begins, or

   b. the point where runoff enters a well-defined channel that may be part of a drainage network or constructed channel such as a waterbar, or

   c. the downslope boundary of a disturbance.

6. Canopy cover- Defined, canopy cover consists of leaves and branches that do not directly contact the soil surface. At Heavenly, this constituent includes trees and high brush greater than 2 feet from the ground surface.

7. Ground cover- Ground cover is the material in actual contact with the soil surface and includes mulch, vegetation growing close to the ground and rock or vegetative debris greater than 3/4 inch across at its narrowest point.

8. Fine root percentage - This was estimated from the vegetation percentage estimated in the ground cover data. Assuming that the area covered by the vegetation above ground is equal to its fine root system below the percentage of fine roots is equal to the percentage of vegetation for a given segment surveyed.

9. Available water - This is defined in WRENNS as the transport agent of eroded material. It is the amount of rainfall or snowmelt remaining following infiltration that can runoff [sic] (overland flow) and transport eroded material. Water availability values vary by slope length and runoff. Further monitoring is required to determine the accuracy of the values currently used in the model.

10. Soil texture- This is based on the assumption that sediment delivery efficiencies are higher on an area dominated by fine textured materials than on an area dominated by coarse -textured materials if the other factors influencing sediment delivery are equal. It is a constant value throughout the Heavenly CWE evaluation derived from the following equation, the information of which is available in the SCS soil survey for the Lake Tahoe Basin:

Texture of eroded material = percent silt + percent fine sand

The soil texture used in the model reflects the texture of eroded material or [sic- for?] only one soil type found on Heavenly. Future soils evaluation will provide enough information to vary the soil texture by soil type.

11. Slope shape- Slope shape plays an important role in sediment delivery. Concave slopes will facilitate more efficient transport of sediment to a stream channel than convex slopes.

12. Delivery distance- This is defined as the distance between the point where overland flow leaves a segment and the point where it enters a defined channel connected to the watershed's drainage network. This channel can be :

    a. a live or ephemeral natural channel;

    b. a gully that empties directly into a stream channel or into a system of channels leading to a stream channel; or

    c. a waterbar that empties directly into a stream channel or into a system of channels leading to a stream channel.

13. Surface roughness- As in general cover, soil roughness affects sediment delivery compared to smooth soil surfaces. Rougher surfaces crate a more tortuous path way [sic] for eroded particles to pass over as well as more surface area for water to infiltrate. This factor ranges from 0 for smooth surfaces to 4 for rough surfaces, generally values used in the model range from 1-4."

Table 1 is an excerpt from an LTBMU table containing field data and other MUSLE factors for specific ski run segments.

The WRENNS model estimates only surface erosion, and does not include gully erosion. During the summer of 1991, on the California side of the ski resort (which includes most of the Heavenly Valley Creek watershed), LTBMU staff used transects to measure rill and gully erosion according to a U.S. Soil Conservation Service (SCS, 1966) procedure. This involves measuring rills encountered along a linear transect for width and depth, calculating the rill area in square inches from width and depth, and dividing the area by 84 to yield the soil loss in tons per acre for the specific plot. Assuming that rills are symmetrical and continuous for a certain distance, a cubic yard value can be derived. Based on the transects, ski runs with rills and/or gullies were assigned higher sediment delivery ratios to reflect the additional sediment production and increased delivery efficiency. These ratios were based on the extensive expertise of the field surveyor and were considered conservative estimates (Holland, 1993).

Disturbance Condition

A disturbance coefficient was applied to roads, to account for soil compaction.. While the WRENNS model automatically calculates a vegetative management factor (VM factor) it does so based on vegetative cover and soil surface conditions. Unpaved roads lack vegetative cover and the soil is compacted. Therefore, a higher VM factor is applied. Using information from Table IV-3 in Chapter Four of the WRENNS Handbook, a VM factor of 1.3 was used in the LTBMU model for all roads analyzed in the Heavenly ski resort (Holland, 1993). VM factors for sediment source areas are included in Table 1.

Data for individual road segments were entered into the LTBMU model to determine sediment delivery. Information for some segments was grouped for areas with similar slope gradients and landscape attributes; e.g., contiguous road segments were grouped together to define a length of switchback or a route adjacent to a creek or a road generally following the same gradient. Tables 2 and 5 include modeled sediment delivery data for groups of road segments.

Natural Sediment Yields

The LTBMU used several methods to estimate natural watershed sediment delivery rates, in order to compare results to ensure greater accuracy. These methods included use of data from a USGS study in the Incline Creek area, estimations using the WRENNS Handbook (USFS, 1980) and Guide for Predicting Sediment Yields (USFS, 1981), and comparisons to field data for suspended sediment in the undisturbed tributary for Heavenly Valley Creek. The USGS data (Glancy, 1988) showed annual sediment yields in undeveloped watersheds between 10 and 100 tons per square mile (0.016 and 0.156 tons per acre). Holland (1993) describes computation of natural sediment yield from the Heavenly ski resort based on methods in USFS (1981), and including a procedural rating for mass erosion hazards as described in Chapter 5 of the WRENNS handbook. The estimate was based on a worksheet with weighted factors for slope gradient, soil depth, subsurface drainage characteristics, soil texture, bedding structure and orientation, surface slope configuration and precipitation input. LTBMU staff determined a numerical rating using these factors, and a graph from USGS 1981, to obtain an average natural sediment rate of 40 tons per square mile (0.0625 tons/acre/year) for the Heavenly ski resort as a whole. LTBMU staff also used the average suspended sediment concentration for the undisturbed tributary of Heavenly Valley Creek between 1981 and 1987 to estimate natural sediment yield; the results corresponded to 7.7 tons per square mile (0.012 tons per acre per year), which did not represent total sediment. (This tributary is ephemeral, and the data included several very wet or very dry years, so results may not be representative even of "average" suspended sediment conditions. The LTBMU is now using another stream, "Hidden Valley Creek", as a reference stream.)

The LTBMU modeling data presented in TRPA (1995) include sediment yield estimates for specific undisturbed "segments" in the portion of the Heavenly Valley Creek watershed within resort boundaries. The 0.03 tons per acre per year figure, together with the 1341 acre watershed area used in the EIR/EIS, gives an overall estimate of 40 tons per year for undisturbed lands in the Heavenly Valley Creek watershed. The latter figure is the one used for undeveloped lands in the TMDL source analysis and load allocations.

Source Analysis

The "baseline" sediment delivery figures used in the TMDL source analysis reflect the modeled total sediment delivery figures for the road, ski run, and undeveloped lands categories in summarized in Table 2. (Model output data are also available for individual road and ski run segments.) The model results reflect the field data collected in 1991

(Table 1). (A subset of randomly selected roads and ski runs is being evaluated each year in relation to effectiveness of BMPs, but no comprehensive field survey of all road and run segments has been done since 1991.) These land use categories are used in the TMDL because they were the categories modeled by the LTBMU, because erosion was modeled slightly differently for roads (e.g., the compaction VM factor) and because different mitigation strategies (abandonment) were used for some roads as opposed to ski runs. (The Heavenly Valley Creek watershed includes about 57 acres within the state of Nevada; the Nevada portion does not include any mapped surface waters. The LTBMU model addressed the watershed as a whole, and it is not possible to separate California and Nevada loading categories.)

Model Results Used in TMDL Load Allocations

Mitigation and Management Factors

The WRENNS/MUSLE model does not account directly for certain management and mitigation activities which are important at Heavenly and which can significantly affect sediment delivery from a ski run or road. Table 3 below summarizes the management and mitigation coefficients the LTBMU model factored into a ski run or road's total sediment delivery value. Many of these coefficients were based upon research in the Idaho Batholith (Megahan and Kidd, 1972, Burroughs and King, 1989).

Table 3. Management and Mitigation Factors for Determining Sediment Delivery from Ski Runs and Roads (from Holland, 1993).

Description	Factor
Construction Timing/Maintenance	
Newly Constructed (first year only)	13.5
Second Year Construction	3.6
Regrading	4.0
Mitigation Measures	
Obliterated	0.05
Graveled	0.55
Riprap Fill	0.90
Successful brush fill barrier	0.93
Rocklined ditch	0.80

The following is an example of the use of the "Construction Timing/Maintenance" coefficients in the LTBMU model. The coefficient for a newly constructed ski run or road reflects significant soil instability during the first and second years following disturbance. A factor of 13.5 is multiplied into the road or run's modeled total sediment delivery for the first year after construction, and a factor of 3.6 is multiplied into modeled sediment delivery for the second year following construction. A ski run with sediment delivery initially calculated at 10 tons per year would, if newly constructed, have an adjusted sediment delivery rate of 135 tons per year (10 tons/yr x 13.5). The following year, estimated sediment delivery would drop to 36 tons/yr (10 tons/yr x 3.6) Thereafter, the estimated sediment delivery would be 10 tons/yr. If the ski run had erosion problems during the third year, its sediment delivery value for that year would be adjusted upwards to a value greater than 10 tons/year. If Best Management Practices (BMPs) such as well placed water bars and revegetation were used, estimated sediment delivery could be adjusted to fewer than 10 tons per year.

As a second example, assume that an unpaved road with an initial modeled sediment delivery of 7.5 tons per year is regraded. Estimated sediment delivery for the first year after regrading is raised to 30.0 tons/year (7.5 tons/yr x 4.0). Modeled sediment delivery drops to 7.5 tons/yr during the following year assuming that BMPs have been applied. If the same road is graveled and its ditch is rock lined, modeled sediment delivery is adjusted to 0.675 tons per year (7.5 tons/yr x 0.45 x 0.20).

Mitigation measures can be combined and their factors summed to reflect additional levels of erosion control. To do this, the factors under the "Mitigation Measures" heading in Table 3 must first be subtracted from 1.0. The resulting "erosion reduction factors" can then be summed. For example, assume that an unpaved road is graveled, its ditch rock-lined, and its fill riprapped. The reduction factors respectively are 0.45, 0.20, and 0.10. Their sum is 0.75. A "sum mitigation factor" of 0.25 is obtained by subtracting 0.75 from 1.0. The initially calculated sediment delivery value for the road is then modified by the sum mitigation factor to obtain a new value reflecting mitigation. Given an initial road sediment delivery value of 9 tons/year, modeled sediment delivery adjusted for mitigation would be 2.25 tons/year (9 tons/year x 0.25).

The LTBMU model allows erosion reduction factors to be summed with the limitation in most cases that mitigation is assumed not to reduce erosion beyond 80 percent (an erosion reduction factor cannot be greater than 0.80 or a sum mitigation factor less than 0.20). However, when roads are obliterated, the model allows elimination of up to 95 percent of the erosion potential, and the mitigation factor becomes 0.05 (Holland, 1993).

The LTBMU also evaluated the water quality impacts of impervious surface within the Heavenly master plan area, but did not include them in the model of sediment delivery because impervious surfaces generally do not contribute sediment. Impervious surfaces do cause increased runoff and may therefore have offsite impacts such as accelerated streamflow and increased erosion downstream. Impervious surface was accounted for in the overall LTBMU evaluation of the water quality impacts of the Heavenly Ski Resort Master Plan (TRPA, 1995, 1996) and mitigation was required for the impacts of impervious surface separately from the watershed restoration program on which the TMDLs are based.

Mitigation Strategy

LTBMU staff modeled sediment delivery reductions expected from ski run and road segments which were to receive specific types of mitigation. These included abandonment and restoration of a number of road segments, and application of BMPs at two different levels of intensity ("TOC" and "HIGH") to other roads and to ski runs. "TOC" is related to a watershed sensitivity index developed for the Heavenly Valley Creek watershed, and indicates that BMPs will bring this segment to a level which is not expected to cause significant cumulative impacts. "HIGH" indicates a level of BMPs which will bring sediment delivery from the segment below the "TOC" level. The modeled sediment delivery reductions are shown in Table 4; the "Reason for Mitigation" column shows road segments to be abandoned and restored ("ABANDON") and differentiates between the "TOC" and "HIGH" strategies for BMPs.

The Heavenly Ski Resort Master Plan includes a remedial erosion control program which targets all road segments with modeled erosion rates of over five tons per acre per year and all ski runs with modeled erosion rates over one ton per acre per year. Mitigation *under the Master Plan* for road segments and ski runs with lower modeled erosion rates was not considered to be necessary. Remedial erosion control projects have been implemented for the impacts of ski resort development in various parts of the Heavenly Valley Creek watershed since the 1970s, which may account for the lower erosion rates for some of these source areas. However, the USFS is now requiring full application of BMPs for *all* disturbed areas in the watershed. Regional Board staff's TMDL instream load allocations reflect the relative percentages of contributions from mitigated hillslope sources, using specific assumptions about BMP efficiency and about USFS plans to apply BMPs to all disturbed areas.

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